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A TEXT-BOOK

OF

PHARMACOLOGY

AND

THERAPEUTICS

OR THE

ACTION OF DRUGS IN HEALTH AND DISEASE

BY

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EIGHTH EDITION, THOROUGHLY REVISED

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PREFACE TO THE EIGHTH EDITION.

The continuous progress in our knowledge of the action of drugs and in their applications in therapeutics has made it necessary to revise this textbook again. How rapid that progress has been is not often recognized, but has been borne in on me by a comparison with an older edition issued in 1903; in the last twenty years the space allotted to remedies for specific diseases in the therapeutic index has increased fivefold. Many of the changes made now are in matters of detail, but others are of greater importance. The advance in cardiac therapeutics is recognized in further alterations in the chapters on digitalis and the cinchona bases; the treatment of ergot had become unsatisfactory owing to the diversity of the alkaloids discussed under it, and I have therefore limited it to the true bases of the fungus and have added a new chapter on histamine action and the related symptoms of anaphylaxis and shock. The cocaine group has been rearranged in the hope of drawing more attention to the substitutes for the original alkaloid. The insulin treatment of diabetes has been allotted a short chapter, and I have devoted another to the vitamins, which has allowed a more logical position to codliver oil than it occupied in previous editions; these two subjects may perhaps be claimed for other studies of the medical curriculum, but their importance in therapeutics justifies their inclusion here, even if the physiologist may regard it as an invasion of his territory. Further changes in the discussions of quinine, thyroid, strychnine and pituitary have been made where necessary. These additions have been compensated by some rearrangement of the chapters, which tends to simplify them, and by the curtailment of the space given to obsolescent drugs.

The text has been embellished with a few of the many references to drugs which are to be met with in general literature, in the hope that they may serve to enliven the subject and perhaps encourage my readers to pursue explorations which will lead them into pleasant pastures. Should they by good fortune reach "the Schoole of Salerne" (1607), they will hardly leave it before reaching the farewell verse:

And here I cease to write, but will not cease
To wish you live in health, and die in peace;
And ye our Physicke rules that friendly read,
God grant that Physicke you may never need.

A. R. C.

Edinburgh, 1924.

PREFACE TO THE SIXTH EDITION.

In this edition the space devoted to many of the less important and less reliable drugs has been further curtailed and others have been omitted altogether from consideration. This appears to be in accordance with the general trend of medical progress, and therapeutics would probably not have suffered from an even more drastic selection. But a text-book must not only describe the virtues of the established remedies, but must also point out the worthlessness of many preparations which still enjoy an unmerited popular reputation. I would appeal to teachers and especially to the members of examining boards to restrict further the drugs which the student has to study. For as long as he has to learn the supposed virtues of a host of obscure substances, he will tend to use them in practice, even if only tentatively. This in turn necessitates their inclusion in the pharmacopœias, which again gives them some standing and perpetuates them as subjects of teaching and examination. If examiners would break this vicious circle, they would greatly lighten the burden of the student, and would render the subject of pharmacology more attractive to him. There is no question that the insistence on numberless preparations of drugs of questionable value has discouraged interest in therapeutics.

On these grounds I have omitted many preparations which are still to be found in the pharmacopœias, but which appear to me to be superfluous. Some chapters have been much curtailed, others recast and expanded, all have been carefully revised. Among those which have been much altered are the chapters on the general anesthetics, opium, digitalis, ergot, and adrenaline. Several new chapters have been added among them those on the new organic arsenical compounds, on atophan and on the pituitary extract. Extensive changes have been made in the classification, which is now based on the organs on which the drugs exercise their most characteristic action rather than on a consideration of the whole of their effects. This new arrangement bears a closer relation to the therapeutic uses than that adopted in former editions. A large number of drugs chiefly used for their local action as antiseptics and disinfectants has been collected into one group and discussed together. I hope that these changes, which I have found useful in my own classes, may prove acceptable to others.

A. R. C.

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A TEXT-BOOK OF PHARMACOLOGY.

INTRODUCTION.

Pharmacology is the study of the changes induced in living organisms by the administration in a state of minute division of such unorganized substances as do not act merely as foods. Many of the best known of these substances are used to counteract the effects of disease, or to reinforce the tissues in their struggle to maintain their functions, when these are rendered abnormal. These substances are known as *drugs*, and the art of applying drugs in disease is *Therapeutics*. Other substances are of little or no value in disease, but are of importance because they act as *poisons*, that is, cause dangerous or fatal symptoms in man or animals, when they are ingested in quantity. The practical study of the effects of these poisons in man—the diagnosis and the treatment of poisoning, and the methods of detecting the poison—is termed *Toxicology*. But the explanation of the symptoms induced by chemical substances belongs to the field of pharmacology, which includes not only the effects of drugs and poisons, but those of any substance which induces changes in the living organism, whether those changes are of benefit to it, injurious, or indifferent.[1]

The substances must, of course, conform to the requirements of the definition. Thus, a needle introduced into the tissues induces effects which are outside the field of pharmacological investigation, because it is not in a state of minute division. But the iron of the needle may be reduced to a fine powder and induce changes in the body which are then the legitimate subject of research. Similarly the drug must be introduced from without, for many active agents are formed within the body, but their study belongs rather to the departments of physiology and pathology; and the effects of organized bodies introduced from without are now studied under bacteriology. Pharmacology is really a department of biology, very closely related to the other sciences included by that term. Thus, as physiology is the study of the life of the normal organism, pharmacology is the study of the organism rendered abnormal by drugs, while in pathology the phenomena of life under disease are examined. All three subjects may be pursued without reference to the practical needs of medicine, and all three are closely interconnected and mutually dependent, for, in many instances, the normal condition of an organ can be recognized only by considering the results of its destruction by disease

[1] It is quite impossible to distinguish between drugs and poisons. Almost all remedies given in excess cause dangerous or fatal symptoms, while many poisons are valuable remedies in small doses. Some bodies may in fact be remedies, foods, or poisons according to the quantity ingested and the method of application.

(pathology), or of its paralysis or stimulation by chemical agents (pharmacology). Similarly, many of the features of disease are now recognized to be due to the presence of unorganized poisons formed in and by the tissues, and it accordingly becomes difficult to define accurately the limits of pathology and pharmacology.

The great interest of pharmacology does not lie in its purely biological aspects, however, but in its relation to the treatment of disease. As long as we are ignorant of how a remedy acts in any disease, the treatment is purely empirical; when the mode of action is understood, much greater accuracy can be attained in the treatment. The object of pharmacology is to explain the mysteries of therapeutics, whether the subject is studied at the bedside or in the laboratory. The exact way in which a drug changes the diseased condition can often be followed only imperfectly in man, and recourse must be had to experiments on healthy or diseased animals to elucidate the principles on which it should be employed. In addition, the experimental investigation of new chemical bodies has very frequently demonstrated properties which are of therapeutic value; almost all the new drugs introduced in the last half-century have found their way to the wards through the experimental laboratories.

Pharmacology is one of the most recent developments of medical and biological science. It is true that from the earliest times attempts have been made to explain the effects of drugs on the then prevailing theories of pathology, but the objective study of the action of drugs on the organism has been a development of the nineteenth century, or it might almost be said, of the second half of it. The study of drugs was termed *Materia Medica* up to this time, and comprised an examination of their botanical and chemical properties along with some account of the diseases in which they had proved of value. This descriptive rather than experimental study has been continued under the name of *Pharmacognosy,* but is now pursued by pharmacists chiefly. Undoubtedly the student of medicine ought to know those characters of drugs which are of importance in modifying their action and application, but it is undesirable that his valuable time should be occupied in the detailed description of crude substances, which he may probably never have an opportunity of seeing in his future practice.

Another subject which now occupies a much less prominent position in medical study than formerly, is *Pharmacy,* or the art of preparing drugs for therapeutic use. Some general knowledge of the methods used is no doubt indispensible to the educated physician, but the details may be left to the pharmacist. Pharmacy will probably occupy a still more subordinate position in medical education as the tendency to include only one or two drugs in a prescription becomes more widespread. As long as a dozen or more components went to make one mixture, it was of importance to know their solubility and their interactions, but with the decay of the complex prescription the study of pharmacy by medical students has certainly become less imperative.

GENERAL THEORIES OF PHARMACOLOGICAL ACTION.

A number of drugs affect the organism only through their obvious *physical* properties, as when an inert oily body is applied to an abraded surface and promotes its healing by protecting it from irritation and from the evaporation of fluid, or when common salt absorbed into the blood changes its osmotic tension, and thus alters the distribution of fluids in the tissues. On the other hand, many effects are due to simple *chemical* reactions; for instance, bicarbonate of potassium may be used to neutralize the hydrochloric acid of the gastric juice, just as it combines with acid in a test-tube, and many of the effects of oxalates arise from their forming insoluble salts with the calcium of the tissues. In the great majority of drug effects, however, no such simple relations as these obtain and the mode of action remains unknown. One view which has been widely held, postulates that where a drug affects a cell it enters into a definite chemical combination with the constituent protoplasm, similar to the ordinary compounds of the chemical laboratory. This theory has not been supported by evidence, and, while it has not been disproved, there are many difficulties in its acceptance; one of these is that the same action may be induced by a series of drugs which have no chemical reactions in common and which therefore cannot be supposed to enter into the same chemical combination with the cell protoplasm. In recent years there has been a tendency to attribute the action of drugs rather to their physical properties, and there can be no question that these play a large part in determining the effects; for example, unless a drug is soluble in the fluids of the body it cannot be absorbed and circulate in the blood, and, similarly, unless it is soluble in the cell contents it may have difficulty in entering the cells. Many drug effects have been ascribed to this selective absorption alone, a drug acting on all cells into which it can enter, by changing the relations of the cell constituents in which it is dissolved; but objections have been raised to this view which cannot be neglected. (See Meyer-Overton theory of narcosis.) Similarly, attention has been drawn to the possibility that some effects may arise from the drugs altering the surface tension of a cell in relation to the surrounding fluids. It has been shown that in some cases in which true chemical combinations were believed to be formed between cell constituents and drugs, the connection is really of the loose nature known as "adsorption compounds," which are best illustrated in the combination of dyes with fibres (see Heavy Metals); the formation of these adsorption compounds is associated with a change of electrical charge and some authorities are disposed to attribute some other pharmacological actions to a similar change in electrical state. Finally, it is believed that in most instances drugs act on a cell only when they have penetrated into its interior, but the virtues of certain remedies have been shown to be due to their failure to penetrate the cells, which leads to an alteration in the relation of the fluids in which they are dissolved and those in the interior of the

cells with which they are in contact (see Salt-action). And Straub has brought forward some evidence that certain very powerful drugs act by altering the cell surface without penetrating into the interior, while others effect changes only as they penetrate the surface, and lose their efficiency as they accumulate in the interior. Changes in the intracellular membranes have been suggested by others as an explanation of most drug effects; it is held that a drug may reduce the permeability of the cellular membranes by altering their electric charges and thus retard the free passage of ions which is necessary for full activity; other poisons may accelerate their movement, and thus increase the activity.

These views have all been supported by a certain amount of evidence, and there is every reason to believe that these physical properties are important factors in the action of some drugs. But it is equally obvious that no one of them will explain the whole of pharmacological action, and there is reasonable doubt whether the whole of the physical characters taken together will suffice for this. From the present confusion the only legitimate conclusion seems to be that the activity of drugs depends on a large variety of factors and that pharmacological action cannot be brought under any one law, either chemical or physical.

This view stands in conflict with a theory which has been widely held, and which postulates that the pharmacological action depends directly on the chemical structure of a drug and may in fact be deduced in large part from a consideration of its structural formula. Plausible arguments in favor of this view have been drawn from the resemblances in action presented by certain chemical groups; for example, a large number of soporifics belong to the group of the simpler methane compounds, and the heavy metals offer certain resemblances in their effects in the body just as they react similarly to some chemical tests. But it is equally probable that these resemblances depend on some physical property which is common to each group, and which has a more immediate bearing on their action than the actual structure. Of course the physical characters, themselves, ultimately depend on the chemical composition, and the reaction in the organism, therefore, ultimately arises from the chemical composition, but as it is at present impossible to derive the physical properties from a consideration of the chemical formula, it appears futile to attempt to derive the action in the organism from it. And whenever an attempt is made to follow the relationship between chemical composition and pharmacological action in detail, the analogy breaks down, because factors which it is impossible to deduce from the chemical structure or formulæ, intrude themselves; for example, the series of lower alcohols of the methyl series show a regular progressive increase in toxicity so that some of the higher members might be expected to form very powerful poisons, but as a matter of experience these prove to be harmless because they become insoluble in the fluids of the body.

STIMULATION, DEPRESSION, IRRITATION.

When a cell is affected by a poison, the extent of its activity is changed but not the kind. The reflex movements may be augmented under strychnine or may be lessened under chloral, but they remain reflex and cannot under any circumstances partake of the nature of voluntary movements. In other words, the effects of drugs are quantitative, not qualitative, the activity of living matter may be changed, but the form which the activity assumes is unchangeable.

Drugs which increase the activity of any organ or function are said to *stimulate* it, while those which lessen the activity are said to *depress* it. Another condition induced by drugs is *irritation*, for although this term is often applied loosely as a synonym for stimulation, the two conditions are not identical. Stimulation is properly used to indicate an increase in the specialized function of a cell, producing, for instance, in the spinal cord an increase in the reflex excitability. Irritation, on the other hand, is used rather in reference to the changes in the conditions common to all forms of living matter, that is, it indicates a change in the nutrition and growth of the cell, rather than in the specialized functions. Irritation may thus be induced in all kinds of tissues and is the commonest change caused by drugs in the less differentiated forms, such as the connective tissues and ordinary epithelia; while stimulation is met with in the more highly specialized cells, such as those of the heart, nervous system, or secretory glands. In many instances the irritant action of drugs may be explained by their known reactions with the proteins of the cell; for example, substances which dissolve proteins, or precipitate them, or withdraw fluid from them, all tend to cause irritation when they are applied to living tissues. In other cases irritation appears to be induced through some action the nature of which is quite unknown.

When stimulation is prolonged or excessive, the protoplasm generally becomes depressed and finally loses its activity entirely (paralysis). Some authorities have asserted that depression is invariably preceded by stimulation, and that stimulation sufficiently prolonged invariably leads to depression and paralysis. Both statements are too absolute, although they are true in the great majority of cases. For example, the action of atropine on the terminations of the cardiac inhibitory nerves is purely depressant. Even the most minute quantities of this alkaloid never increase the activity of these terminations, for if a quantity too small to weaken them is ingested, it has apparently no effects whatever, and as the dose is increased, the first effect is depression.

Depression, whether induced directly, or following on stimulation, has been shown in several instances to resemble the fatigue induced by the prolonged exercise of the normal organ, and it is probably true that depression and fatigue are, in all instances, identical in appearance, although not necessarily identical in cause. For example, the phenomena of fatigue of the terminations of the motor nerves in

muscle resemble exactly those induced by curara, but in the former the cause may be that the conducting substance of the nerve ends has been used up by the repeated passage of impulses, while in the latter the conducting substance is so changed that it becomes incapable of transmitting stimuli to the muscles. The final result is, of course, the same; there being no available conducting substance, impulses fail to reach the muscle. But the fatigued terminations rapidly recover, as conducting substance is reformed, while the curarized recover only when the poison is eliminated.

In most cases an excessive dose of a stimulating poison leads to depression and paralysis. The cell becomes functionally dead, but if the failure of its function does not involve the death of the organism, it may recover and reassume its ordinary function as if no stage of inactivity had intervened. Excessive irritation, on the other hand, leads to actual death and disintegration, from which there is no recovery. For example, the cells of the spinal cord are first stimulated and later paralyzed by a large dose of strychnine, but this is not fatal to cold-blooded animals, and after a few days the spinal cord regains its normal function, as the poison is eliminated. On the other hand, the injection of an irritant into the subcutaneous tissues causes dilatation of the vessels, effusion of fluid, and increased growth and rapid division of the cells. If only a small quantity be injected, this condition is recovered from, although it generally leaves evidence of its presence in the form of an increase in the fibrous tissue. But if the irritation be intense, the cells undergo degeneration and die, and an abscess is formed. The cells thus destroyed can never recover as the paralyzed ones do. They are either absorbed, or removed by the opening of the abscess, and their room is filled by the overgrowth of the neighboring tissues.

When the effects of a drug are only temporary and the tissue returns to its normal activity when the drug is eliminated, the action is said to be *reversible*; this is the case for most forms of stimulation and depression and for mild irritation. When the cells do not recover but have to be replaced by new growth, the action is *irreversible.*

DISTRIBUTION AND CONCENTRATION.

The distribution of a drug in the different tissues and organs of the body must influence its action; and it might be expected that those organs which contain it in largest proportions would show greater changes than others in which it is present in smaller amounts. But this is found not to be true in many instances; for example, the liver often contains larger quantities of alkaloids than any other tissue, yet no symptoms may arise from this organ. The relative concentration in which a drug is present in the different tissues thus does not determine the extent to which these are involved in the action. But if an organ reacts to a drug, the degree of its reaction depends on the concentration in which the drug is presented to it, and the problem in therapeutics

is very generally to bring up the concentration in one organ to the efficient threshold without involving other organs; for example, in chloroform anæsthesia the object is to cause sufficient concentration in the brain without involving the heart and respiration.

The concentration of a drug in a cell depends in the first instance on the concentration in which it is present in the surrounding fluids, for the passage into the cell appears to be a simple diffusion which follows the law of mass action. And in many cases there seems to be no greater concentration than is in accord with diffusion, the drug being present in the cell in the same concentration as in the fluid; for example, carbolic acid is not actively taken up by bacteria. In other instances the drug is deposited in the cell in some form of combination, chemical or physical, and the diffusion continues until the cell may contain the whole of the drug and the surrounding fluid is free from it; an instance of this is presented by the accumulation of mercury in bacteria. As the drug is accumulated in the cell it may finally reach a strength that provokes reaction, but in some instances the drug accumulates in large amount without interfering with the functions of the cell.

The concentration of a drug in the tissues depends primarily on the dose given, but this is modified by the rate of absorption and the rate at which the body frees itself from the drug by excreting it, or changing it into harmless forms. Small divided doses of a remedy may thus never cause the same symptoms as the administration of the same amount undivided. The most striking instance of this is offered in anæsthesia, for during an operation of an hour's duration much larger amounts of chloroform or ether are taken into the tissues than would be fatal if inhaled more rapidly; the fatal concentration is not reached because while absorption is going on throughout the stage of anæsthesia, excretion is proceeding equally rapidly.

ELECTIVE AFFINITY OF DRUGS. PROTOPLASM POISONS.

Most drugs have an elective affinity for certain definite tissues. Thus, some attack the heart only, others the central nervous system and others the terminations of the motor nerves in muscle. Among the cardiac poisons again, some act on the ventricle, others on the auricle, and among the poisons of the central nervous system, some act primarily on the cortex, others on the medulla oblongata and others on the spinal cord. This elective affinity is not merely a question of degree, as is sometimes stated, for a drug which has a powerful action on the brain may have no effect on the heart except when administered in such quantities as alter the physical characters of the blood. A drug may even alter different structures in diametrically opposite directions. Thus, atropine depresses certain nerve terminations, but stimulates the brain; and curara, which paralyzes the peripheral terminations of the motor nerves, stimulates the spinal cord. In some instances the immunity of a cell to the action of a drug may perhaps

be explained by the latter failing to penetrate into its interior, but this is not true in all cases.

The fields of activity of different drugs vary greatly in extent. One may comprise only the terminations of the secretory fibres in the sweat glands (agaricin), while another, which affects these in the same way, may involve many other terminations in its action (atropine). Most poisons, however, while acting on a certain narrow area in small doses, extend the limits of their activity when larger quantities are ingested. Thus, a poison which acts in small doses on the medulla oblongata only, may, when exhibited in larger quantities, involve the spinal cord and the brain, and in still greater concentration may affect the heart and other organs. No poison is known that acts equally on all organs and tissues, but those which have a wide field of operation are often known as *protoplasm poisons*. These paralyze any form of living matter when they are brought in contact with it in sufficient quantity, but if they are injected into the blood and thus distributed equally throughout the body, they invariably select some special organ as the chief seat of their activity. This is exactly parallel to the behavior of chemical agents in the laboratory. For example, acetate of lead added to a solution of a chloride, or of a sulphate, precipitates it, but added to a mixture of the two, throws down more of the sulphate than of the chloride. Nitrate of silver, on the other hand, precipitates the chloride only. Acetate of lead may be compared to the protoplasm poisons, nitrate of silver to those with a less extensive field of action. As protoplasm poisons affect a large number of different forms of living matter, it follows that they alter the nutrition rather than specialized functions. Many of them cause irritation; others are used to destroy or retard the growth of microbes and are known as disinfectants or antiseptics.

REMOTE, LOCAL, AND GENERAL ACTION.

Drugs change directly only those organs and tissues with which they come into immediate contact. But the alteration of one part of the organism very often entails that of another to which the drug may not have access, or for which it has no special affinity, because impulses are transmitted through the nerves, or changes are induced in the circulation and nutrition. Thus irritation of the skin may alter the rate of the pulse by impressions being transmitted by the cutaneous nerves and reflected along the inhibitory nerves of the heart. Similarly a poison that weakens the heart may induce disorder of the respiration, from the circulation being deficient in the medulla oblongata; and depression of the brain may lessen the oxidation in the muscles, because it leads to lessened movements. These secondary changes, which are not due to the direct action of the drugs on the organs concerned, are known as *remote* or *indirect* effects.

The *local* action of a drug is that induced at the point of application before it enters the circulation, the *general* or systemic action is that

due to its elective affinity for certain organs to which it is carried by the blood. The local effects are very often entirely different in nature from the general action, for a drug may act as an irritant at the point of application and as a depressant to the brain when it is carried to it in the blood. Local effects may be induced wherever the drug can be applied—in the skin, the alimentary tract, the respiratory passages, and the other mucous membranes. They also occur in the subcutaneous tissues when the poison is injected hypodermically, and in any of the deeper organs and tissues which can be reached by the needle of the syringe. Local remedies may cause irritation, or may protect the surface from irritation, may depress the sensory end-organs and cause local anæsthesia, or lessen secretion, or alter the functions at the point of application in many other ways. They may also have remote effects, as has been mentioned. Many drugs have only a local action, because they are not absorbed, are absorbed in inactive forms, or are excreted or deposited as rapidly as they pass into the circulation, so that enough is not present in the blood at any one time to induce general effects. On the other hand, many powerful poisons have little or no effect at the point of application, but possess an elective affinity only for some organ to which they are carried by the circulation.

SALT-ACTION.[1]

Salt-action is the term applied to a series of reactions which occur from the physical effects of solutions, and which are analogous to changes in dead tissues and are explained in the same way. Salt-action is elicited by any substance which can circulate in the body in sufficient concentration; it is oftenest seen under the salts of the alkalies, but is equally elicited by sugar, urea, and other harmlesss organic substances; on the other hand the more powerful poisons never reach the concentration in the tissues which is necessary to elicit salt-action.

Salt-action depends on the relative ease with which a salt and the water in which it is dissolved diffuse into the cells with which they come in contact. When a solution of salt is brought in contact with one containing sugar, the salt molecules and ions rapidly diffuse into the sugar solution and the sugar molecules into the salt solution until the whole becomes homogeneous, each part containing the same amount of sugar and salt. In the same way if a living cell be brought into a solution of sugar, there is often a diffusion in both directions, the sugar passing into the cell and the salts of the cell passing into the solution until the fluid within and without the cell becomes identical in composition. If much sugar diffuses into the cell this may disturb the equilibrium, and changes in the activity of the cell may follow, or if the salts and other diffusible bodies in the cell escape in large quantities into the fluid, this may again change the life processes in the cell. Marked

[1] A more detailed account of the salt-action in different organs will be given in the Chapter on Sodium Chloride and Water, to which the reader is referred. Here only the general principles are dealt with.

reactions may thus arise from changes in the constituents of the liquids surrounding a cell even though these constituents are comparatively inactive themselves; and the reduction in the amount of a constituent of the plasma may prove as harmful as its presence in excess, by causing the escape of essential constituents of the cells.

Pure water diffuses readily into all cells and causes disturbance in their functions from reducing the concentration of their soluble constituents. And some solids also appear to diffuse with little difficulty into many cells. But it is found that most dissolved substances meet with some resistance in entering cells, and that different tissues also vary in this relation, one set of cells taking up many salts with readiness, while another set permits the passage of few of these and rejects others. When a salt can penetrate a cell readily, the water in which it is dissolved also finds no resistance to its entry, and the contents of the cell are thus diluted as much as if they had been exposed to pure water. On the other hand, if a salt cannot penetrate into a cell, it holds back a certain proportion of the water in which it is dissolved, and osmotic currents are set up between the soluble bodies and water in the interior of the cell and the solution outside it. If the latter is the stronger in osmotic pressure (hypertonic solution), the water of the cell diffuses into the external solution; if the osmotic pressure of the cell contents is the higher, the movement of the water is toward the interior and the solution is said to be hypotonic; if the osmotic pressure in the cell contents is equal to that of the solution (isotonic solution) there is no movement of the water and the volume of the cell remains unchanged. The behavior of a cell and the surrounding fluid is thus of the same character as that observed between the fluids on the two sides of a membrane in the physical laboratory; but no dead membrane is known which differs so much in its behavior to various salts as the living cell, and the behavior of fluids and salts is further complicated by the fact that the permeability of the different cells varies greatly.

As an example of salt-action the reactions of the red-blood cells may be given: water penetrates into these readily, and when the cells are placed in distilled water, it passes into them until they swell up and burst; ammonium chloride penetrates readily also, and in solutions of this salt the red cells behave almost as if they were placed in distilled water; sodium chloride hardly penetrates these cells, and when they are placed in a solution of sodium chloride of the same osmotic pressure as that in the interior of the cell (isotonic), there is no movement of water into the interior since the water of the solution is held back by the sodium chloride; if a solution of lower osmotic pressure (hypotonic) is employed, a certain amount of water is taken up from it by the cell, the weaker sodium chloride being unable to compete with the attraction of the stronger solution in the interior of the cell. On the other hand if a solution of higher osmotic pressure (hypertonic) be used, it withdraws fluid from the cell, which shrinks, because the salts in the interior are unable to retain the water against the stronger concentration outside. The behavior of the epithelium of the intestine toward these

salts offers a contrast to that of the red-blood cells, for the chlorides of sodium and of ammonium are both readily absorbed by the intestine; on the other hand the sulphate of sodium fails to penetrate the red cells and enters the intestinal epithelium with great difficulty.

Soluble salts exist in the body mainly as ions, and each ion exerts the same osmotic pressure as an undissociated molecule. And each ion possesses an independent pharmacological action. For example, when cyanide of potassium is given, the action may arise from either the potassium or the cyanide ion, and when potassium hydrate is applied, the effects may arise from either the K-ion or from the HO-ion. In many instances one ion is so powerful that the other may be neglected; thus when potassium cyanide is given, the cyanide acts in such minute quantities compared with the comparatively inert K-ion that the latter is never present in sufficient quantity to elicit symptoms. On the other hand when the ions are more equal in power each has to be taken into account in analyzing the action; thus when magnesium sulphate is administered, the Mg-ion and the SO_4-ion each bear a part in the effects.

Many drugs are not dissociated in the tissues and act only as molecules and not as ions; thus C_2H_5HO does not dissociate the HO-ion as KHO does, and none of the characteristic effects of this ion are elicited by the former. This has often given rise to confusion, especially in connection with organic bromine compounds. The bromide ion has a valuable action which follows when the dissociable bromides are given, but no such effects follow from such bodies as $CHBr_3$ because these do not dissociate the Br-ion. Compounds which dissociate poisonous ions are thus to be differentiated from others in which the same constitutents are present in undissociable combinations. Another example of this is offered by the toxicity of potassium cyanide, which liberates the CN-ion, and the inactivity of potassium ferrocyanide, which contains CN but does not dissociate the CN-ion but the more complex, harmless ferrocyanide ion.

CONDITIONS MODIFYING THE EFFECTS OF DRUGS.

The effects of drugs on the living organism are subject to some modifications in certain individuals and under some conditions, which it is of importance that the physician should recognize, as the dose has to be altered when they are present. One of these is the **Size and Weight.** If the same amount of a poison be distributed through the tissues of a large individual as of a small one, the concentration is lower in the organs of the former and less effect is therefore observed. This has been ascertained chiefly in animal experiment, in which the effects of drugs can be estimated much more exactly than in man, but it undoubtedly holds good for human beings also. Very large individuals, then, require a somewhat larger dose than ordinary persons, while in treating individuals of small stature, the dose has to be reduced.

The **Age** of the patient has also to be taken into account in prescrib-

ing. Children ought to receive much smaller doses than adults. The more powerful action of drugs in children is due mainly to their smaller size, in part to the more active growth of certain tissues and to the less complete development of others, such as the central nervous system. The dose for a child is generally calculated according to Young's formula, in which a fraction obtained by dividing the age by the age + 12, is taken as the proportion of the adult dose required. Thus, for a child of four years, the dose would be $\left(\frac{4}{4+12}=\right)\ \frac{1}{4}$ of the adult dose, for one of one year $\left(\frac{1}{1+12}=\right)\ \frac{1}{13}$ of the adult dose.

Neither Young's formula nor any of the others which have been devised in its stead is to be regarded as more than a very general approximation, to which there are many exceptions. For example, the narcotics, particularly opium and its preparations, must be given during the first year of life in much smaller quantities than are indicated by Young's rule, while alcohol may be administered in comparatively large doses.

The usual dose advised has to be modified for children then, and may be taken as that suitable from 20–60 years. After this age is passed, it is again reduced somewhat, so that from 70–80 about $\frac{3}{4}$ of the adult dose is advised, and after 85 it may be reduced to $\frac{1}{2}$. There are exceptions to this rule also, large doses of the purgatives, for example, being often necessary in old people.

Sex.—Women generally require somewhat smaller doses than men, because of their smaller size. It is often stated that their tissues also react more strongly to drugs, but this is certainly not a general rule.

Temporary conditions also influence the activity of drugs. Thus, *after a meal*, a poison is absorbed more slowly than when it is taken fasting, and any local irritant action is also less marked, because the drug is diluted by the contents of the stomach. *Affections of the stomach and intestine* may also modify the effects of drugs; little absorption occurs in the stomach except of drugs that are soluble in oils and lipoids, and if the movement of the stomach is lessened or any spasm of the pylorus is present, they may reach the absorbing mucous membrane of the bowel more slowly and thus their effects are retarded or slight; irritant drugs naturally cause more disturbance of the stomach in these cases. Vomiting and diarrhœa, of course, tend to lessen the action of drugs by removing them rapidly from the alimentary canal.

During *pregnancy*, purgatives have to be used with great care, because they induce congestion of the pelvis, and may lead to miscarriage. Drugs acting on the uterus, or inducing a marked fall of blood pressure, are to be avoided because the former may cause the evacuation of the uterine contents, while the latter may lead to asphyxia of the fœtus. Many drugs pass from the mother to the child, and this is to be borne in mind, as quantities which are insufficient to poison the former may have more serious effects on the latter. During *lactation*, it is important to remember that active bodies may be excreted in the milk, and may either act on the child or render the milk distasteful to it. In

menstruation, purgatives are to be avoided, as they tend to increase the flow, and all very active drugs are to be used with care or abandoned temporarily.

The **Time of Administration** has also some influence on the effects of drugs. The body is generally more resistant in the morning than in the evening, especially in the case of narcotic drugs; thus a dose of a soporific which may have little or no effect in the early hours, induces sound sleep when given in the evening, because the brain is already fatigued and depressed.

Idiosyncrasy is used to denote an unusual effect for which no explanation can be found. Some persons react more readily than usual to the ordinary dose, while in other instances, a much larger quantity can be taken without any effect. Others, again, show symptoms which are entirely different from, and which may, in fact, be diametrically opposed to those ordinarily observed. These idiosyncrasies are naturally more frequently seen and are better known, when they arise from widely used drugs. Thus the modern antipyretics have so often induced abnormal symptoms that these are well known, but it is not improbable that if other drugs had been used, or rather abused, to the same extent, they would be found to induce unusual reactions in an equally large number of individuals. An idiosyncrasy, as has been said, cannot be explained in the present state of knowledge, but some conditions which have been termed idiosyncrasies are probably due to abnormally rapid, or to retarded absorption or excretion. Idiosyncrasies are not confined to human beings, for not infrequently one animal reacts quite differently from others of the same species.

As has been mentioned, one form of idiosyncrasy consists in the failure of the individual to react to the ordinary dose of a drug. This is known as **Tolerance**,[1] and this particular form of idiosyncrasy may be termed *congenital* tolerance. Certain species of animals tolerate quantities of drugs which would be fatal to others of the same size. In fact, so frequently is this the case that it is impossible to determine the fatal dose of any drug on an animal from experiments performed upon others of a different species, even though it be nearly related. One of the most remarkable examples of this form of tolerance is met with in the hedgehog, which resists large doses of many very active poisons. Another well-known example is the tolerance of the rabbit of large quantities of atropine.

A form of tolerance which is a matter of everyday observation is that induced by the prolonged use of a drug, which has been called *acquired* tolerance, or mithridatism, from the tradition that Mithridates protected himself in this way from the danger of poisoning. The most familiar example of this form of tolerance is that acquired for tobacco (nicotine); the first cigar often induces violent poisoning, but if a habit be formed, considerable amounts of nicotine may be absorbed without apparent harm, because the tissues become accustomed to the presence

[1] *Gunn.* Physiological Reviews, 1923, iii, p. 42.

of small quantities of nicotine, and thus fail to react to it. Nicotine, in fact, becomes a normal constituent of the tissues. This tolerance is entirely different from the immunity induced by toxins (see Toxins), and it is desirable that the two terms should be kept distinct.

An important form of tolerance is the resistance developed by trypanosomes and other parasites for certain drugs (see Organic Arsenic Compounds).

Very often while some tissues acquire tolerance for a poison, others fail to do so, and either react in the same way as before or may suffer from the prolonged use of excessive quantities; for example, although after prolonged use morphine loses its action on the brain, so that large doses have to be given to relieve pain, tolerance is less developed in the bowel, so that constipation continues to be induced by smaller amounts; similarly in a dog tolerant to morphine, the inhibitory cardiac centre retains its sensitiveness to it. Some animals fail to develop tolerance for certain drugs; for example the rabbit remains sensitive to morphine after prolonged treatment. It is to be noted that tolerance is soon lost if the drug be discontinued for some time. This is of great importance in cases of opium-eating, for a person who has taken opium for a long time acquires a tolerance for the drug, so that sometimes enormous quantities are required in order to induce the ordinary effects; but if the habit be discontinued for some time, the tolerance is lost, and a dose which would formerly have had little effect may now induce dangerous poisoning. The prolonged use of one drug may establish tolerance for others of the same class. Thus chronic drunkards are not influenced by large quantities of alcohol, and are also more resistant to the action of chloroform than ordinary persons, this being due to the fact that chloroform and alcohol act on the same nerve cells in the same direction, and probably induce the same changes in the protoplasm.

In some instances when tolerance is established for a drug, it is found that the tissues destroy more of it than previously (morphine and alcohol), or excrete it more rapidly, as is said to occur under atropine in some animals, or perhaps absorb it less readily (arsenic). The drug thus never reaches the same concentration in the tissues and the absence of action is thus partly explained. In addition to this, however, the organs normally affected become less susceptible to the drug; for though in morphine tolerance much more is destroyed than in normal persons, enough remains in the blood to cause deep narcosis in ordinary people, yet no symptoms are induced in the patient.

The **Cumulative Effect** of drugs is another phenomenon caused by their continued ingestion. Small doses of certain drugs taken repeatedly for some time eventually cause symptoms which are much more marked than those that follow the first dose. This seems due to the accumulation of considerable quantities in the tissues. The absorption may be more rapid than the excretion, and each new dose thus adds to the total quantity in the blood and organs more than is lost in the same time by excretion. The classical example of cumulative action is that of digitalis, but it is much more frequently induced by such drugs as

mercury, arsenic, or the iodides, for the so-called chronic poisoning induced by these is really an example of cumulative action. Another form of cumulation is said by Straub to occur in chronic lead poisoning; here the symptoms appear to arise not from the poison collecting in the tissues until it reaches an efficient concentration, but from the cumulative effect of continually repeated injuries from the presence of lead, though these injuries are individually too slight to be noted. Cumulative action may occur along with tolerance, as has been stated. Thus the tolerance of certain tissues for nicotine does not protect others from the effects of the abuse of tobacco.

Synergists.—The presence of another drug having the same effects in the body often increases the action of a remedy to an unexpected extent. This is the ground for the prescription of several remedies acting in the same way.[1] For example, several purgatives prescribed together often act more efficiently than any one given in quantity equal to all of them. It is quite impossible to explain this except by assuming that, although all are alike in their chief features, they differ in the details of their reactions, so that parts of the alimentary canal which might escape one are affected by another, and the mixture thus acts more universally than any one of the components. Other examples of synergism are offered by the narcotics, for it has been shown that a mixture of morphine and chloral, for example, is more efficient than either administered alone in larger dose. Another recent example is offered by the use of mercury and arsenical compounds in syphilis, which reacts better than when either of these is used alone. The importance of synergism is often exaggerated, but in some examples the increased activity of one drug in the presence of another is remarkable.[2]

On the other hand, a drug may fail to elicit any symptoms if an **antagonistic** substance is present in the body. Thus in cases where a powerful nervous depressant, such as chloroform, has been inhaled, strychnine may have little or no effect on the spinal cord in doses which would normally increase the reflexes to a marked extent. In the same way, if the terminations of the inhibitory fibres of the heart are paralyzed by atropine, a poison which normally slows the heart by stimulating these terminations will have no effect in the usual doses; but if larger quantities are given, the paralyzing action of atropine is overcome, the heart is slowed and the conduction through the terminations is restored. A larger dose of atropine may then again paralyze the restored terminations.

Similar modifications of the effects of drugs may be induced by poisons formed by pathological changes in the tissues, or by an unusual state of irritation or of depression of the tissues themselves. For example, the excitable uterus of pregnancy may react by contraction to certain drugs which excite both the motor and the inhibitory nerves and which in the more inert non-gravid organ cause relaxation. Simi-

[1] The less important ones are sometimes termed adjuvants.
[2] *Führer.* Arch. f. exp. Path. u. Pharm., lxxxii p. 51.

larly, in hot weather and in tropical climates, purgatives are found more efficient than in colder climates, because the mucous membrane is more irritable than usual, as shown by the frequent occurrence of diarrhœa without drugs. In the same way when an antagonistic poison is formed in the tissues in the course of a disease, a drug may have little or no effect.

Pathological conditions often modify the effects of drugs to a very considerable extent, and in a way which cannot be explained at present. For example, the antipyretics reduce the temperature in fever, but have no effect on it in health; the bromides lessen the convulsions in epilepsy, but have much less effect in depressing the brain in normal persons. The question may therefore be raised whether the examination of the effects of drugs in normal animals is of much value in indicating their therapeutic action. But in reply it may be said that in a large number of instances drugs are given, not in order to act upon the diseased tissues, but upon healthy ones. The object of the therapeutist is very generally not to restore the diseased tissue but to relieve it from work, and to allow it rest so as to promote its restoration by nature. For instance, in diseases of the cardiac valves, drugs are given, not with the object of restoring their integrity, but to act upon the healthy heart muscle, and to obviate the disturbance of the circulation which is caused by the destruction of the valves. In inflammation of the kidneys, the physician seldom attempts to reduce the inflammation by the action of drugs on the cells involved, but confines his attention to removing by other channels the products of tissue waste, which would normally be excreted by the kidney. So that in most instances drugs are given to act on normal tissues, or on tissues which are so little affected by disease that they react to remedies in the same way as the normal. In other cases the action of drugs on diseased tissues or on the causes of disease may be investigated by inducing the disease in animals, as has been done very largely in recent years in various infectious diseases.[1]

METHODS OF ADMINISTRATION.

The effect of a remedy is often determined very largely by the method in which it is administered As regards the local action, this is sufficiently obvious, for an irritant applied to the skin could scarcely be expected to cause the same symptoms as if it were applied to the stomach and intestine. But the same holds true for the general action in most instances, because some tissues and organs absorb much more rapidly than others, and a larger quantity of the drug therefore passes through them into the blood in a given time. Thus, if a poison which is absorbed slowly, be rapidly excreted, so little of it may exist in the blood and tissues at any given time that no effects are induced, while if it be rapidly absorbed by some other method of administration, the same dose can exert some action before it is excreted.

[1] This method of investigation and its results are sometimes known as *chemotherapy*, but they do not differ in essentials from those of pharmacology.

Drugs are applied for their **Local Action** to the skin, to the mucous membranes of the alimentary, respiratory, and genito-urinary tracts, and to the conjunctiva and cornea. Not infrequently they are injected by means of the hypodermic needle into the subcutaneous tissues for their local effects, and the attempt is continually being renewed to treat even the deeper tissues and organs locally by the injection of remedies into them. The objects of local medication are very diverse, and can be treated of only in connection with the individual drugs. The methods of application are also so numerous that only a few of the chief can be mentioned. Drugs intended for application to the skin are often formed into salves or ointments (unguenta) by mixing them with oily or fatty substances, which adhere to the skin and do not dry up, and which in addition to serving as a means of applying an active substance, protect the surface from the air and from irritation. Other preparations for application to the skin, such as the plasters (emplastra), resemble the ointments in their general characters, but also give mechanical support and bind surfaces together from their being spread on paper or cloth, which thus serves as a flexible splint. The collodions and cerates resemble the plasters, the oleates the ointments. In addition to these special preparations, drugs may be applied to the skin in solutions, or as powders, or solid masses may be used to cauterize it.

The methods of applying drugs to the alimentary tract and to the lungs for their local action are for the most part similar to those used for drugs which are intended to be absorbed. The mouth and throat may be washed out with solutions, which are gargled (gargarismata), or may be treated with powders, or lozenges (trochisci), which are slowly dissolved and thus permit of a more prolonged and constant action in the mouth than is possible if the drug be swallowed immediately. The nose may be washed out with solutions of active drugs, or powders may be drawn into the nostrils as snuffs; the latter often cause sneezing, and are sometimes known as sternutatories, or errhines. The larynx may be treated locally by the application of powders or of very small quantities of fluids by means of the laryngoscopic mirror and probe. Solutions are generally used for application to the conjunctiva, but a more permanent effect can often be obtained from ointments, lamellæ, or powders which are less liable to be washed away by the tears. The urethra, vagina and uterus are treated by the injection of solutions, or by ointments and powders. Bougies, which are occasionally advised, are formed by incorporating an active drug in some substance which is solid at ordinary temperatures, but melts when introduced into the organ and allows the drug to come into contact with the surface. The rectum may similarly be treated by the injection of drugs in solution or suspension (enemata), or by the use of suppositories. Drugs are not infrequently applied by the rectum in order to elicit their action after absorption, but much oftener for their local action on the bowel. Enemata may be either large (a pint or more) or small (2–5 c.c., $\frac{1}{2}$–1 fl. dr.). The large enemata are used

either to wash out the intestines, and may then contain an antiseptic or astringent, or to induce peristalsis and evacuation of the bowel, when they are made up of water with or without soap or other slightly irritant substances. The small enemata are used chiefly to induce evacuation, and contain more irritant substances, such as glycerin alone or along with some more active body. Suppositories are formed of cacao-butter, which is solid at room temperatures, but melts at the temperature of the rectum.

Drugs whose **General Action** is to be elicited after their absorption are given by the mouth, except when some special character in them or in the disease renders some other method preferable. They may be given by the mouth in solution in water, alcohol, oils, or other more or less indifferent bodies. The disagreeable taste of many remedies, however, often precludes this method, and these may be ordered in the form of pills, or in capsules, which are formed of gelatin or similar substances and are dissolved in the stomach and intestines. Very often the disagreeable taste may be concealed by the addition of sugar, or of some strongly tasting but agreeable body, such as a volatile oil. Insoluble drugs may be given as powders, as they have little or no taste. Powders are also used as a means of administering soluble drugs, if they have not a disagreeable taste and have no marked local action, but very deliquescent drugs should not be given in this form. Insoluble drugs are sometimes ordered in suspension in mucilaginous fluids; and oils which are distasteful to many people, may be given mixed with water and gums (emulsions).

The rate of absorption from the *alimentary canal* varies greatly with different drugs and also with the form in which they are administered. The first point will be treated of in connection with the individual drugs. As regards the second, it may be stated that drugs are more rapidly absorbed when they are swallowed in solution, and that when much inert and insoluble matter is associated with them, their absorption is much retarded. Thus, common salt passes more rapidly into the blood when it is dissolved before being taken than when it is swallowed dry, and morphine is absorbed more quickly when it is administered pure than when, as in opium, it is mixed with a mass of gums and other bodies. This fact is taken advantage of in practice by giving drugs in solution when rapid absorption is desirable, and by giving less pure forms when the local action on the stomach and bowel is to be elicited. The more concentrated the solution, the greater is the irritant action on the stomach, and thus where irritation of the stomach is desired, either the solid drug or a strong solution is given; but as a general rule the local action on the stomach is to be avoided, and drugs are therefore ordered in as dilute solution as is possible without increasing the bulk to too great an extent. It is to be noted that drugs which are insoluble in the test-tube may be rendered soluble by the action of the gastric and intestinal juices, while many which are given in solution, are precipitated by the proteins in the stomach.

The great mass of drugs absorbed from the stomach and intestine

is carried to the liver before reaching the general circulation, and this is of great importance in determining their effects in the body, as some of them are retained in that organ, and are either entirely destroyed or escape so slowly that they have no perceptible effect.

Another important method of administering drugs for their general action and also for their local effects is by inhalation into *the lungs*. Only volatile drugs can be used thus for their general action. They are absorbed very rapidly owing to the extensive surface to which they are applied, and also because volatile substances penetrate the tissues more readily than others. The best examples of inhalation are offered by the general anæsthetics, chloroform and ether. Most substances absorbed by the lungs are also excreted by them, and this leads to an important practical point in regard to the anæsthetics. For the passage of gases or vapors through the lining epithelium of the alveoli depends in most instances upon their partial pressure, that is, upon their concentration in the air and blood respectively. Accordingly, when the air contains more chloroform vapor than the blood, the anæsthetic passes into the blood, but as soon as the condition is reversed, and the blood contains more chloroform than the air of the alveoli, it commences to pass backward. The more concentrated the vapor inhaled, the more chloroform is contained in the cubic centimeter of blood, and the greater is the action on the nervous centres and the heart.

Less volatile substances are sometimes inhaled into the lungs for their local action, and even non-volatile bodies suspended in a spray of vapor may be thrown into the respiratory passages, but it may be questioned whether these last really reach the alveoli except in traces.

Drugs are also applied to *the skin* in order to elicit their general action. Volatile bodies are certainly absorbed by it, although much more slowly than by the lungs or by the stomach and intestine. Solutions in water of non-volatile drugs are not absorbed from the skin, but solutions of certain remedies in alcohol, oils, fats, ether, and some other substances which are capable of dissolving or mixing with the fatty covering of the skin, are absorbed fairly rapidly if they are rubbed in thoroughly. This method of application (inunction) has been used chiefly for the absorption of mercury, as the local action on the stomach and bowel is thus avoided. (See Mercury.) Alkaloids do not appear to be absorbed by the skin even when dissolved in oils or alcohol.

An attempt has been made to carry some electrolytic drugs through the skin by means of the electric current (*ionic medication*) and it was hoped that a high local concentration might be attained, for example of salicylate in the knee-joint, when the current was passed through it. But the quantities thus introduced are very small, and while some concentration occurs in the skin and subcutaneous tissue, they are not carried into the deeper structures in significant amounts.[1]

The *hypodermic method* is of comparatively recent origin, but is

[1] *Inchley.* Jour. Pharm. and Exp. Ther., 1922, xviii, p. 241.

being more widely used every year. In it drugs are injected through a fine hollow needle into the subcutaneous, or, in the case of more irritant substances, into the muscular tissue, where they meet with fewer sensory nerves. Absorption occurs more rapidly than when drugs are given by the mouth, the local action on the alimentary canal is avoided, and the physician is more certain that the whole of the remedy is effective, provided it is soluble and is not precipitated at the point of injection. At the same time, the method has certain drawbacks, the chief of which are the pain of the injection and the danger of injecting a powerful remedy into one of the subcutaneous veins. Hypodermic injections should be made only by the physician or trained attendant, for incalculable injury has been done by entrusting patients with the syringe, particularly for the injection of morphine and cocaine. The needle and syringe ought to be disinfected, and the substance injected should be aseptic, and this renders the method inconvenient. As a general rule, solutions in water or in dilute alcohol are used for injection, but the insoluble salts of mercury have also been injected, suspended in oil (see Mercury). Irritant drugs are to be avoided as far as possible, as they cause great pain, swelling and sometimes suppuration or sloughing, even when the injection has been carried out aseptically. If there is any doubt as to the irritant action of a drug, the injection should be made into muscle (gluteus) as disastrous results have followed from ignorance of the local action of such remedies as quinine or lime salts. Ringer's solution should be used instead of plain water when possible. Hypodermic injection is used very largely to elicit the general action of a remedy, but also for the local effects, as when cocaine is injected in order to produce local anæsthesia. Solutions of inert bodies have also some anæsthetic action, probably owing to their mechanical action on the sensory nerve fibres. As the absorption from the subcutaneous tissues is so much more rapid than that from the stomach and intestine, when the drug is in perfect solution, the dose has to be reduced. As a general rule, about one-half of the ordinary amount is sufficient.

Deeper injections are sometimes made for their local action on the organs. Thus, antiseptics have been injected into lung cavities, caustics into tumors, local anæsthetics into the spinal canal, and direct applications have been made to the nerves in sciatica and other similar disorders.

Intravenous injection is the most certain and rapid method of bringing drugs into the circulation and tissues, and has long been used in experiments on animals and more recently in man in diseases in which it is desired to induce a definite concentration of a remedy in the blood rapidly (syphilis, malaria, urgent heart failure, etc.). A long hypodermic needle is passed directly into one of the superficial veins of the arm and after all air has been expelled from the needle and syringe, the drug is slowly injected in solution which may vary from 1 c.c. to 200 c.c. The drug must be in complete solution and must not react with the protein of the blood; thus strongly acid drugs and dissociable salts of the heavy metals should be avoided; on the other hand drugs which are too irritant

for hypodermic injection may sometimes be given intravenously. Ringer's solution should be used as a solvent and the most perfect asepsis should be aimed at. The dose is smaller than that given by the mouth, but no general rule can be given, This method is to be used only as an emergency measure except in the use of salvarsan.[1]

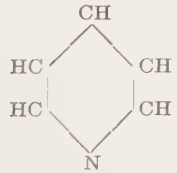
Drugs are occasionally applied by the *rectum* for their general action, as has been mentioned. The local effects on the stomach are avoided by this method and some of the drug reaches the circulation without passing through the liver; morphine and opium are sometimes administered thus. The rate of absorption from the rectum as compared with that from the stomach and bowel is still a disputed point, and some physicians recommend that the dose be reduced to three-fourths, while others recommend one and one-half times that given by the mouth.

Drugs are not administered by the *other mucous membranes* for their general effects, but it must not be forgotten that symptoms may arise from their application to them for their local action. Similarly, drugs applied as dressings to *wounds* or *abrasions* have very often given rise to severe or fatal poisoning from being absorbed into the blood and tissues.

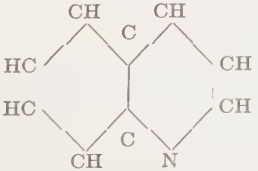
THE CHEMICAL CHARACTERS OF DRUGS.

Many substances which induce changes in the living organism are comparatively simple chemical compounds. In the inorganic materia medica are found many salts, bases and acids, and a few uncombined elements, such as mercury and phosphorus, while organic chemistry offers hydrocarbons, alcohols, ethers, phenols, ketones, aldehydes, acids, and many other compounds which require no special mention. But some groups of substances which occur widely in plants require some discussion before the individual members are taken up severally.

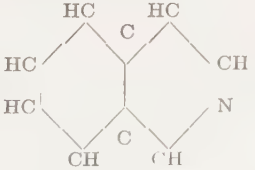
The first group of these is formed by the **Alkaloids**, which are substituted ammonias, and have a more or less strongly alkaline reaction, so that they are often known as the vegetable bases. They contain carbon, hydrogen, nitrogen, and, as a general rule, oxygen, although some of them, such as coniine, are devoid of it. Like ammonia, they combine with acids readily without eliminating hydrogen, and the salts thus formed resemble those of ammonia in many respects, among others in being thrown out of combination by the fixed alkalies. Many vegetable alkaloids are derived from pyridine, quinoline and isoquinoline by the addition of hydrogen, and generally by the substitution of one or more of the hydrogen atoms by side chains of greater or less complexity.



Pyridine.



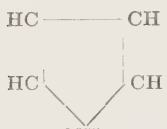
Quinoline.



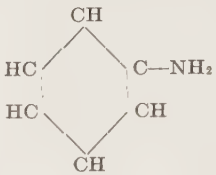
Isoquinoline.

[1] *Eggleston*, International Clinics, ii, p. 27.

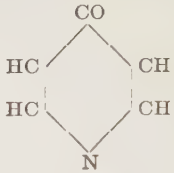
But others appear to be derivatives of the pyrrol and oxazine groups, while in others the nitrogen is attached to radicles belonging to the methane or open-chain series; some artificial alkaloids are derivatives of aniline.



Pyrrol.



Aniline.



Oxazine

Finally the purine bodies (see Caffeine group) may be included although they are only feebly basic.

Some of the vegetable alkaloids have been formed synthetically in the laboratory, and the constitution of some of the others is perfectly well known, but many of them have not yet been isolated, and there are probably others whose existence is not even suspected. These vegetable alkaloids occur in almost all parts of plants, although they are found in greatest abundance in the seeds and roots. The same alkaloid is often found in most of the plants of a genus, or it may occur in one or two species of a genus and in other plants which are in no way related. Very often several alkaloids are found in a plant, and these may differ entirely in their action on animals, although not infrequently all the alkaloids of a plant resemble each other in their effects. The alkaloids are found most abundantly in dicotyledonous plants, but some are obtained from the monocotyledons. Muscarine, ergotoxine and other bases are found in the fungi, and alkaloids have been isolated from the suprarenal capsule of animals and from the skin of the salamander.

The alkaloids are very often only slightly soluble in water, but form salts which are generally more soluble. Many of the bases are dissolved by ether, chloroform and amyl alcohol, while the salts are insoluble in these. Both bases and salts are generally fairly soluble in alcohol. The alkaloids are precipitated from solution by a large number of reagents, of which the most important are the chlorides of platinum and of gold, tannic acid, phosphotungstic and phosphomolybdic acid, the double iodides of potassium and mercury, and of potassium and bismuth, and iodine held in solution in water by potassic iodide. The hydrates and carbonates of the alkalies and the alkaline earths precipitate the alkaloids from solutions of the salts in water, a point of some importance in prescribing these bodies.

In cases of poisoning when the alkaloid has been taken by the mouth, it may be precipitated in the stomach by dilute alkalies or better by tannin solutions. The poison should then be removed by inducing vomiting or by washing out the stomach with the stomach tube.

Another important class of vegetable poisons is formed by the **Glucosides** (glycosides), or saccharides, which are esters (compound

ethers) composed of sugars and hydroxyl substances, and which liberate sugar when they are heated with acids, or sometimes with alkalies, or when certain unorganized ferments act on them. The sugar formed in this way is often glucose, but not invariably so; the other decomposition products have been identified only in a few instances. Many of the glucosides contain only carbon, hydrogen and oxygen, a few have nitrogen in addition, and one or two sulphur. In some instances the remainder, after the sugar is split off, is an alkaloid, *e. g.*, solanidine. Glucosides differ greatly in their solubility in water and alcohol; comparatively few of them are soluble in ether. Some of the glucosides are powerful poisons, others have little or no action.

Resins, an ill-defined group, are found in many plants, and are characterized by their smooth, shining fracture, and by their insolubility in water and solubility in ether, chloroform, volatile oils, benzol and, in many cases, in alcohol. They seem to be formed in plants by the oxidation of volatile oils, and are often acid or anhydride in character, while others are apparently alcohols or esters. The resins are almost invariably composed of several different substances mixed together. Many of them are local irritants, and some are poisonous in comparatively small quantity from the powerful action they exert on the intestine.

Oleoresins are solutions of resins in ethereal oils (see page 61), which lend them a characteristic odor and taste.

The term "*Balsam*" is often used as synonymous with oleoresin, but most writers restrict it to those oleoresins which contain benzoic and cinnamic acid along with other constituents.

Gum-resins are mixtures of resins and gums, generally containing some volatile oils. They are insoluble in water, but the resin is suspended in it by the gum. On the other hand, the resin is dissolved by alcohol, while the gum remains insoluble.

Gums are amorphous, transparent substances, composed of carbohydrates of the formula $(C_6H_{10}O_5)_n$ and are thus nearly related to cellulose and starch. Some of them are soluble in water, while others merely swell to a jelly in it; they are insoluble in alcohol. They generally occur in plants in combination with calcium, magnesium or potassium; they have no poisonous action, but form a protective covering for irritated surfaces, and are largely used to suspend in water substances which are insoluble in it, such as resins and oils.

Volatile oils occur in plants in large numbers. (See page 61.)

Fats, oils, sugars, acids, starch, proteins, coloring matter, ferments and other bodies which occur in plants, and are contained in many of the preparations used in therapeutics, are not generally possessed of any action of importance.

THE PHARMACOPŒIAS AND PHARMACOPŒIAL PREPARATIONS.

Almost all governments have found it necessary to regulate the preparation of drugs used in therapeutics, and for this purpose issue

at intervals codes of instructions defining the characters of the drugs and giving the exact formulæ according to which they are to be prepared for use. These codes are known as **Pharmacopœias**, and some differences exist between those of different countries, although the most important drugs are found in all of them. All the drugs used in therapeutics are not found in the pharmacopœias, for these are issued only at intervals of several years, and in the meantime valuable remedies may be introduced. The official definition of therapeutic substances is of advantage to both physician and pharmacist, as it assures the former that the drug he prescribes will have a uniform quality, wherever in the country it is dispensed, while the pharmacist is saved from the continual preparation of remedies in different forms, by their being prescribed in one recognized strength.

The pharmacopœias contain a large number of pure substances such as salts, acids, bases, alkaloids, and these require no further description. On the other hand, many of the drugs are given in an impure form, either because the active principle is unknown, or because its isolation is attended with difficulty and expense. Thus many of the vegetable remedies are presented in the pharmacopœias as solutions or solids which contain not only the active principle but gums, sugars, coloring matter, and many other impurities. These are provided in different forms to allow of variation in their administration. In addition, the pharmacopœias contain a number of official prescriptions, that is, mixtures of active substances in such proportions as are ordinarily prescribed. These are generally designated by the addition of "compound" (compositus) to the name of the chief ingredient. Most pharmacopœias continue to use Latin in the titles of the drugs, and this is not due to mere pedantry or conservatism, as is often stated. For the popular name of a drug is often used for several different substances, while the Latin name in a prescription indicates that drug which is known by the term in the pharmacopœia. In the same way it is found necessary to maintain Latin terms in botany and zoölogy in order to define the species accurately.

Many crude or unprepared drugs are found in the pharmacopœias, such as leaves, roots, flowers, or even whole plants. These are used chiefly for the preparation of other more readily applicable remedies, but are sometimes prescribed as powders or in pills.

The following preparations[1] are official:

a. *Aqueous Preparations.*

Aquæ, medicated waters, generally contain only traces of some volatile substance, such as an ethereal oil or chloroform, in solution in water, and these are used in prescriptions as more agreeable to the taste and smell than pure water but have no further effect. In the U. S. P. the solutions of ammonia, and hydrogen peroxide are also included under aquæ, but these

[1] The student is advised to omit the following list for the present, and to refer to it only as he takes up the preparations of the individual drugs. Most of these preparations are found in both pharmacopœias. Those which occur only in the British are indicated by B. P., while those which are confined to the United States are marked U. S. P.

are used only to elicit the specific effects of these drugs and are powerful poisons. In the B. P. these strong solutions are included in the liquores.

Liquores (U. S. P.) are solutions in water of soluble substances. Many of these are one per cent. in strength.

Liquores (B. P.) are solutions in the widest sense, in water, alcohol, or other fluids.

Decocta, or decoctions, are impure solutions of vegetable principles, which are obtained by boiling parts of plants in water.

Infusa, or infusions, are solutions obtained by soaking parts of plants in water, which may be hot or cold, but is not kept boiling. Infusions and decoctions are weak preparations and decompose rapidly so that they are used only when recently prepared.

Misturæ, or mixtures, are generally preparations in which substances insoluble in water are suspended in it by means of gums or similar viscid substances. But some of them contain only soluble bodies.

Emulsa (U. S. P.), emulsions, are formed by suspending oils in water by means of gums or other viscid bodies. The B. P. contains no official emulsions, the corresponding preparations being known as *misturæ*.

Mucilagines, mucilages, are solutions in water of gums, starch, and similar colloid bodies.

Magmas (U. S. P.), or milks, are suspensions of bulky, white insoluble preparations in water.

Syrupi, syrups, are strong solutions of sugar in water, which may be used alone, or may be impregnated with more active bodies. Similar preparations formed with honey instead of syrup (sometimes known as *mellita*) are official, as Mel Rosæ (U. S. P.), Mel Boracis (B. P.).

Lotiones (B. P.), lotions, or washes. This term is used to designate two preparations of mercury, the black and yellow wash.

b. *Alcoholic Preparations.*

Spiritus, spirits, are solutions of volatile bodies in alcohol, and often owe their chief action to the solvent and not to the drug contained in it.

Elixiria (U. S. P.), elixirs, differ from spirits chiefly in containing sugars, which are added in order to improve their taste.

Tincturæ, tinctures, are solutions in alcohol of medicinal substances, which are generally formed by soaking parts of plants in it. They contain both volatile and non-volatile ingredients, but the latter are generally the more important.

Fluidextracta (U. S. P.), *Extracta Liquida* (B. P.), fluidextracts, are prepared from plants by forming solutions in water or more frequently in alcohol, and evaporating them until the solutions contain as many cubic centimeters as the original crude drugs weighed in grammes; that is, the volume of the fluid extract corresponds to the weight of the crude drug. When the active principle is assayed, however, the liquid extract is diluted to contain a definite amount of it, and without reference to the quantity of the crude drug used.

The tinctures and fluid extracts are the most commonly used liquid preparations, and most of the important drugs are prepared in one or both of these forms.

c. *Other Fluid Preparations.*

Glycerita (U. S. P.) or *Glycerina* (B. P.) are solutions of medicinal substances in glycerin.

Collodia, collodions, are solutions of medicinal substances in collodion.

Aceta, or medicated vinegars, are solutions of medicinal substances in vinegar or acetic acid.

Linimenta, liniments, embrocations, are preparations in which active remedies are dissolved or suspended in dilute alcohol, oils, or water. They generally contain an oil or soap and are intended to be applied to the skin.

d. *Solid and Semi-Solid Preparations.*

Extracta, extracts, are formed from solutions such as tinctures, decoctions, or infusions by evaporation, which is continued until there remains a solid mass. The extracts thus contain all the substances which are taken up by the solvent, except those which are driven off or decomposed at the temperature at which evaporation is carried on.

Pilulæ, pills, are globular masses of small size, such as admits of their being easily swallowed. They are formed from extracts, or from powders, by the addition of some substance to give them the necessary cohesion and consistency. Pills generally weigh 0.1–0.3 G. (2–5 grs.). The U. S. P. determines the composition and size of the official pills, so that the doses can be modified only by ordering several pills to be taken at one time. The B. P. leaves the pills unformed, so that they may be prescribed of any size. The Pilulæ of the B. P. really correspond not to the Pilulæ, but to the Massæ of the U. S. P.

Massæ (U. S. P.), masses, are preparations made up of the proper consistency for pills. They are invariably prescribed in the form of pills.

Confectiones, confections or electuaries, are soft, solid preparations consisting of sugar or honey impregnated with some more active body.

Suppositoria, or suppositories, are intended for insertion into the rectum, urethra, or vagina, and are, except in one or two cases, formed by mixing the active ingredient with cacao-butter. Suppositories for the rectum are conical in shape and weigh about a gramme (15 grs.). Those for the urethra (*bougies*) are of the same weight, but are pencil-shaped, while the vaginal suppositories are globular, and weigh about 3 grammes (45 grs.).

Pulveres, powders, are simply dry substances in a state of fine division. Most of the official powders are mixtures of several active bodies.

Triturationes (U. S. P.), triturations, are formed from powders by diluting them with nine parts of sugar of milk.

Tabellæ, tablets (B. P.) are formed of chocolate in which an active drug is incorporated, and weigh 5 grs. or less.

Trochisci, troches, or lozenges, are solid masses, generally of a flattened shape, and consist of powders or other bodies, incorporated in sugar and gum.

Lamellæ (B. P.), or discs, are small discs formed of gelatin with some glycerin, each weighing $\frac{1}{50}$–$\frac{1}{30}$ gr. They are impregnated with an active drug, and are applied to the conjunctiva in order to elicit the local effects.

Unguenta, ointments, salves, are soft, oily substances which are applied to the skin by rubbing. (See page 50.)

Cerata (U. S. P.), cerates, resemble ointments, but are rendered harder by the addition of wax. (See page 50.)

Emplastra, plasters, are adhesive bodies of a still harder consistency than cerates, and soften only when heated.

Chartæ, papers, are preparations of active substances which are spread in a thin layer upon paper.

Unofficial Preparations.

Cachets, are thin discs of dough of the shape of a soup-plate and varying from $\frac{1}{2}$ in. to $1\frac{1}{2}$ in. in diameter. When two of them are placed together with their concave sides toward each other, they form a receptacle in which powders are dispensed. The edges stick together when they are moistened. A somewhat similar method of dispensing is in gelatin *capsules*, which may be hard or soft, and which are made in different sizes. The hard capsule is used for solids, the soft for liquids. Sometimes the latter contain as much as 15 c.c. ($\frac{1}{2}$ fl. oz.), but these are difficult to swallow.

Tabellæ, tablet triturates, or compressed tablets, are formed from fine powders which are moistened and rendered coherent by some liquid and then compressed in moulds. They are generally about 5 grs. in weight, and disintegrate in the stomach more rapidly than other preparations.

Cataplasmata, or poultices, are not official preparations now, but are in common use. They are generally made of linseed meal, oatmeal, or bread crumb, which is formed into a paste with hot water, enclosed in thin cotton or linen and applied to the skin. Mustard and other remedies may be added to the poultice in order to induce special effects, and in some cases a poultice consists merely of drugs enclosed in a cloth sack, as in charcoal or spice poultices.

Enemata, clysmata, or clysters, are liquid substances injected into the rectum for their local or general effects. (See page 33.)

BIOLOGICAL ASSAY.

The accurate use of drugs in therapeutics involves that the amount of active principle given in each dose must be known, or at any rate must not be subject to irregular variations. In most cases the strength of a preparation can be determined by ordinary chemical methods, and this is required for most of the more powerful substances used in therapeutics. This cannot be done for certain important drugs, however, because the active constituents are insufficiently known, or when known cannot be isolated quantitatively. This has led to the method of biological assay, in which the strength of a preparation is estimated by its effects on living animals or tissues. Biological assay was first used industrially to determine the strength of the antitoxic sera, and soon afterward Houghton introduced it to regulate the strength of the preparations of the digitalis series, from which it has been extended to several other substances; it has now received recognition in the U. S. Pharmacopœia.

The principle underlying biological assay is that a certain quantity of a drug will always produce the same degree of deflection from the normal in the same animal or in animals of the same species. This is not absolutely true, for many conditions may alter the extent to which an animal reacts to a drug, and every precaution must be taken to keep the conditions identical in making these tests. For example, the reaction varies inversely with the weight of the animals, and these must be taken as nearly as possible of the same weight and age or, if this is not possible, the dose must be calculated in terms of the weight of the animal. And when great accuracy is required, the test must be done upon a series of animals sufficient to eliminate the variations and idiosyncrasies that cannot be controlled. These tests require special training and laboratory experience and are very time-consuming. The method is not likely to be substituted for chemical assay when the latter is available, and it may be regarded in most cases as merely a stop-gap which allows the strength of drugs to be controlled before the chemical methods have been developed. At the same time, when both methods have been compared, it has been found that their results are in fair agreement, and the quantity required for the biological assay is generally much smaller than that necessary for a chemical estimation.

In biological assay the object is to compare the effects of a preparation with those of a standard, and wherever possible this standard should be a pure chemical substance. For example, the digitalis preparations are assayed against one of the glucosides of the group, and

dried suprarenal gland against pure adrenaline. When the drug contains an unknown active principle or a number of active constituents in unknown proportions, this is not possible and the standard must be obtained by estimating a number of good samples and taking an average of their activity.

The U. S. Pharmacopœia requires the biological assay of Cannabis and its preparations and of Liquor Hypophysis, and advises that of Digitalis, Squills and Strophanthus, Aconite and Suprarenal gland. The methods are shortly given here, and further details are given in the U. S. Pharmacopœia, but these are insufficient without a complete laboratory course.

Cannabis.—Cannabis is assayed by observing the lowest dose of the preparation which given to a dog causes incoördination and failure of equilibrium. The drug is best given in the form of pills which may be formed from the residue left on evaporation of the fluid extract or tincture; but fluid preparations may be used, if the alcohol is carefully evaporated off and replaced by water. The dog should be accustomed to the laboratory and to the observer, and as some animals are more sensitive to the drug than others, or at any rate betray the failure of coördination sooner, one should be selected that is fairly susceptible. The pill or fluid is given by the mouth, and the animal is watched for signs of lessened coördination during the next two hours. The effects are compared with those of a standard preparation which has been carefully made and has been tested on the same animal previously. If the effects from the unknown preparations are weaker than those of the standard, new experiments are made at intervals of three days, using larger amounts until the relative activity of the two preparations is found. The quantities of the standard preparations which cause definite symptoms are for the fluid extract 0.03 mil for each kilogram of body weight, for the extract 0.004 G., and for the tincture 0.3 mil.

Digitalis, Strophanthus and Squills are tested by finding the minimal quantity required to arrest the frog's heart in systole within one hour. The frogs should be healthy animals, carefully stored and weighing 15–25 G. The preparation to be tested should have its alcohol evaporated off if necessary and is diluted with 0.7 per cent. saline. The frogs are carefully weighed and each receives an injection, the amounts being calculated in terms of the weight so that a series is formed of which the lowest dose may correspond to about half the usual fatal one and the highest to about twice as much. The frogs are killed at the end of an hour and the heart exposed. The highest doses will have arrested the ventricle in complete systole, while the auricles are distended; the lowest doses may not have arrested it at all, while in some cases midway it may have stopped in diastole. The lowest dose which has caused systolic stand-still is taken as the type, and a fresh series of frogs is injected with doses of about this amount, some being above it and some below. These will give a closer approximation to the absolute minimal dose and fresh series are poisoned until the observer is satisfied with the constancy of his results.

Frogs vary in their susceptibility to the glucosides according to the season of the year and it is, therefore, necessary to control the assay by comparing the effects of a standard; for this purpose ouabain is injected into a series of frogs and the lowest dose causing systolic stand-still is ascertained. In typical experiments it is found that 0.0005 mg. of ouabain per gram of frog suffices to cause systole, and if the results of an assay vary much from this, it indicates an abnormal condition of the frogs and a proportional correction has to be introduced in the assay of the digitalis.

The standards adopted in the U. S. P. are as follows:

Ouabain	0.0005	mg.	per G.	of frog.
Digitalis tincture	0.006	mil	"	"
Strophanthus tincture	0.00006	"	"	"
Squills tincture	0.006	"	"	"

It may be noted that the tincture of strophanthus is given as a hundred times as strong as that of digitalis by this method, while in the clinic it is rather the weaker of the two; the explanation is that strophanthus taken by the mouth undergoes destruction in the intestine to a larger extent than digitalis. The assay method cannot be used to compare the strengths of different drugs but only to compare preparations containing different proportions of the same active principles; for this reason the use of ouabain as a standard for digitalis preparations is unsatisfactory.

Suprarenal Gland.—Suprarenal gland preparations may be assayed by comparing the rise in blood-pressure in anæsthetized dogs caused by intravenous injections of the preparation and of a solution of adrenaline respectively. The crude gland has been so largely replaced by adrenaline and its salts in therapeutics that this assay is of little importance.

Hypophysis Solution.—Hypophysis solution is assayed by observing the contraction caused by it in the uterus of the virgin guinea-pig. The uterus is excised and suspended in oxygenated Ringer's solution and its movements are registered by attaching it to a lever writing on a rotating drum. The addition of pituitary preparations causes a marked contraction and this is compared with one caused by a definite amount of ergamine, the ergot alkaloid. The hypophysis solution corresponds in activity to a solution of one in a thousand ergamine hydrochloride; each should cause the same amount of contraction when diluted by Ringer's solution twenty thousand times; better assays will be possible when a standard obtained from the hypophysis is available for comparison.

Ergot.—Ergot preparations may also be assayed by the amount of contraction they cause in the isolated uterus, but this is not recognized by the Pharmacopœia.

Aconite.—Aconite preparations are assayed by determining the smallest quantity necessary to kill guinea-pigs of 250–350 G. weight within twelve hours when injected hypodermically. Tincture of aconite should prove fatal in a dose of 0.0004 per gram of guinea-pig.

PART I.

SUBSTANCES WHICH ARE CHARACTERIZED CHIEFLY BY THEIR LOCAL ACTION.

This class contains a very considerable part of the drugs included in the pharmacopœias, although it bears a smaller proportion than formerly to the other classes. There is still, however, in it a large number of drugs which have practically identical effects, and there is no question that it might be considerably curtailed without loss to therapeutic practice. Many of its members are irritants, and these have been subdivided for convenience into groups according to the organs on which they exert their chief action and the purposes for which they are used in therapeutics, as gastric, intestinal, cutaneous irritants. Others act as protectives, covering injured surfaces (demulcents, emollients), and still others precipitate the proteins on the surfaces to which they are applied (astringents). Others seem to act chiefly by affecting the taste and the digestion. Finally the drugs used to destroy intestinal parasites, and those that are employed to act on bacteria are discussed.

I. DEMULCENTS.

A large number of colloid substances—chiefly gums, dextrins, sugars and starches—owe their use in medicine, not to any changes they produce in the cells with which they come in contact, but to the fact that they are cohesive and serve to protect surfaces mechanically. When they are applied to a sensitive surface, they retard the movement of fluid or air against it and thus preserve it from the effects of these agents. This may be illustrated by familiar examples in which the taste of food is altered by their presence, although they have often no taste or odor in themselves. Sugar dissolved in mucilage tastes less sweet than in water, and acids are also less appreciated, as may be observed in many fruits. For example, the raspberry contains more acid and less sugar than the currant, but in the former the acid taste is concealed by the presence of large quantities of colloids, so that the raspberry is regarded as a sweet fruit, the currant as an acid one. Even cold is felt less when a colloid substance is present in the fluid swallowed; thus, ice-cream or iced milk does not feel so cold on the tongue and throat as frozen water, because the colloid protein substances form a protecting layer over the surface, and prevent the cold mass from reaching the sensory terminations so freely as it otherwise would. A

number of experiments carried out by Tappeiner[1] show that other organs may be protected in the same way by colloid solutions. Strong salt solution applied to a motor nerve first stimulates and then slowly paralyzes it, but Tappeiner found that both of these effects are much less marked if the solution be made up with mucilage instead of with water, because the salt does not reach the nerve so readily. In the same way, intense pain is caused in a wound by strong salt solution, but is much less severe if the solution contain colloid material.

When demulcents reach the stomach, they act as protectives in some measure so that the reflexes from the epithelium are less active; and irritants cause less inflammation if they are suspended in demulcents than if they are dissolved in water; at the same time the presence of colloid unabsorbable bodies may increase the efficiency of purgatives by preventing their absorption in the upper part of the bowel. The digestion of proteins outside the body is retarded by the presence of the demulcents, and probably this is also true of the process in the stomach. Colloid bodies also retard the absorption of fluids from the stomach and bowel, and this leads to a feeling of distention, which is much less marked if the same amount of fluid be swallowed without colloid; for instance, water is absorbed more rapidly than milk or beer.

The colloids are absorbed slowly, and probably only in a condition of semi-decomposition. After absorption, they are oxidized in the tissues and therefore act as foods to some extent, although their slow absorption prevents their being of much value. They have, of course, no effect as demulcents after absorption, but the large quantity of fluid with which they are generally taken may be of benefit in some conditions.

Demulcents are used to cover inflamed surfaces; in tonsillitis, for example, they may be applied as gargles, or better by sucking lozenges containing them. They are not often applied externally for this purpose, as they are liable to serve as media for the growth of microorganisms. In gastric and intestinal catarrh their use is objectionable for the same reason, their slow absorption leading to decomposition with the formation of irritants, which may do more harm than is counterbalanced by their protective action. Instead of demulcents, some of the oils, such as olive oil (p. 52), have been recommended as protectives in disease of the stomach and intestine.

In acute irritant poisoning the demulcents are often of great value, as they protect the stomach wall from the effects of the poison. The best remedy in these cases, because the most readily obtainable, is milk or white of eggs.

Their effects in retarding the absorption of other remedies may be taken advantage of. Thus opium is prescribed when the local action on the bowel and stomach is desired, while the pure alkaloid, morphine is administered for its effects after absorption.

Demulcents are often given instead of pure water in cases where it

[1] *Tappeiner.* Archives internat. d. Pharmacodyn., vol. x., p 67

is desired to administer large quantities of fluid, as they have more "body" and are more agreeable to the taste. Thus, barley water or some other demulcent may be advised in order to assuage the thirst of fever, or to dilute the urine when it is too concentrated or too acid.

Demulcents are often used as the basis of enemata which are intended to be absorbed, because solutions containing colloids are less irritant and therefore less liable to set up peristalsis than pure water. For this purpose starch solution is generally used.

Bayliss has advised the addition of 6 per cent. of gum acacia to the saline solution used for intravenous injection, in order to increase its viscosity to that of the blood and to delay its elimination through the kidneys.

Some of the gums, notably acacia and tragacanth, are seldom advised as demulcents, but are often prescribed in order to hold in suspension in water such insoluble bodies as resins and oils, or to give cohesion to pills and lozenges.

Preparations.

Acacia (U. S. P.), **Acaciæ Gummi** (B. P.) (gum arabic), a gummy exudation obtained from Acacia Senegal, consists of the potassium, magnesium and calcium salts of a weakly acid substance, arabin, or arabinic acid ($C_6H_{10}O_5$). It is soluble in equal parts of water, and is used as a demulcent, but more largely as a vehicle for other drugs.

Mucilago Acaciæ (U. S. P., B. P.). Dose, 15 mils (4 fl. drs.).

Syrupus Acaciæ (U. S. P.).

Tragacantha (U. S. P., B. P.), a gummy exudation from various species of Astragalus, contains salts of arabin and tragacanthin. Tragacanthin differs from arabin in not dissolving, but merely swelling up into a jelly in water. Tragacanth is used chiefly to suspend heavy powders in water.

Mucilago Tragacanthæ (U. S. P., B. P.). Dose, 15 mils (4 fl. drs.).

Glycerinum Tragacanthæ (B. P.), a solution of tragacanth in glycerin and water.

Amylum (U. S. P., B. P.), or starch, may be formed into a jelly by boiling in water, and may then be used for the same purpose as the demulcents.

Glyceritum Amyli (U. S. P.), *Glycerinum Amyli* (B. P.), is a jelly formed by heating starch with water and glycerin.

Amygdala Dulcis (U. S. P., B. P.), or sweet almonds, the seed of Prunus amygdala dulcis, contains a fixed oil and emulsin, a ferment, but, unlike the bitter almond, no amygdalin. When triturated with water it forms an emulsion, or mixture, which is bland and demulcent.

Emulsum Amygdalæ (U. S. P.).

Pulvis Amygdalæ Compositus (B. P.), contains sugar and acacia with almond.

Glycyrrhiza (U. S. P.), **Glycyrrhizæ Radix** (B. P.), or liquorice-root, the root of Glycyrrhiza glabra (var. glandulifera), is used as a demulcent, and more largely to flavor medicines. It has a pleasant, sweet taste, owing to the presence of Glycyrrhizin, an acid glucoside.

Extractum Glycyrrhizæ (U. S. P., B. P.).

Fluidextractum Glycyrrhizæ (U. S. P.), *Extractum Glycyrrhizæ Liquidum* (B. P.). Dose, 2 mils (30 mins.).

Pulvis Glycyrrhizæ Compositus (U. S. P., B. P.), contains senna and sulphur. Dose, 4 G. (60 grs.).

Mistura Glycyrrhizæ Composita (U. S. P.), "*Brown Mixture*," contains opium, antimony and spirits of nitrous ether. Dose, 10 mils (2½ fl. drs.).

The extract is largely used in the form of lozenges for its demulcent action, and is frequently used to make up pills. It is slightly laxative, and may be used as a pleasant aperient for children; the compound powder is more reliable for this purpose owing to its containing senna and sulphur. The brown mixture is used in cough and in catarrh of the air passages.

Numbers of other substances are used as demulcents in domestic medicine, and are found in different pharmacopœias. Examples of these are sassafras pith (*Sassafras Medulla*), slippery elm (*Ulmus*), marshmallow root (*Althæa*), linseed (*Linum*), barley (*Hordeum*), salep, verbascum and quince seeds. Iceland moss is a lichen (Cetraria islandica), and contains starch bodies together with acids, which can be removed by soaking in dilute alkaline solutions for some time. Irish moss or Carragheen (*Chondrus*), a seaweed gathered on the coasts of Ireland and Massachusetts, contains a carbohydrate, carrageenin. The decoction forms a jelly when cold, and was formerly supposed to form a valuable food in illness, but it is of little value for this purpose, for only about $\frac{1}{10}$–$\frac{1}{5}$ of the jelly is solid matter, the rest water. Couch-grass, the rhizome of Agropyrum repens (*Triticum*) is used in the form of a decoction as a beverage in fever, and to dilute the urine. It has a certain popular reputation as a diuretic in suppression of the urine, calculus, etc., but this is entirely unmerited, for it increases the urine simply by the water given with it.

II. EMOLLIENTS.

Emollients are bland, oily substances which are applied to the skin to protect it from irritation, and to render it softer and more elastic; they thus bear the same relation to the skin as the demulcents to the mucous membranes. Their effect in rendering the skin softer and more pliable may be due in part to their penetration into the surface layers, but may also be explained by the slight congestion induced by the rubbing and massage used in their application.

The older emollients were chiefly animal and vegetable fats and oils, but several newer drugs of this class are derived from petroleum. The effects of these drugs when applied to the skin are purely local. No doubt some small percentage is absorbed into the tissues, but this has no known effect in man, and although the fats and oils are valuable foods when taken internally, this plays no part in their effects when applied to the skin.

The emollient preparations promote the absorption by the skin of drugs dissolved in them, because they mix readily with the thin layer of oily sebaceous matter which covers it. The active substances dissolved in them therefore come into intimate contact with the absorbing cells lining the ducts of the glands, while watery solutions are separated from the living cells by a layer of sebum. If this layer be dissolved off by alcohol, watery solutions are also absorbed rapidly, and alcoholic solutions are absorbed as quickly as oily solutions, because the alcohol is miscible with the sebum. The absorption by the skin varies considerably according to the emollient used, and it is found that some drugs are taken up more easily from one ointment, others from another; the difference doubtless arises from the relative solubility in the emollient and in the absorbing cells, but is still to be investigated. Aqueous solutions come into more intimate contact with the cells of the mucous

membranes and with the subcutaneous tissues, and are therefore more readily absorbed by these than oily solutions. To ensure rapid absorption, a drug should be dissolved in some emollient if it is to be absorbed by the skin, in water when it is to be administered internally or hypodermically. Solutions in oil of such antiseptics as carbolic acid are much less powerful than those in water, because carbolic acid being more soluble in oil fails to diffuse into the watery protoplasm of the microbe, for which it has less affinity. But antiseptics which are more soluble in water than in oils are said to be equally active in both solvents.

The emollients are applied as protectives in abrasions, cuts, bruises, chapped hands, burns; they are less often used alone in extensive skin diseases, but are usually prescribed in these as the basis of ointments in which other remedies are incorporated. There is no question that the protection afforded to the part and the exclusion of the air and of germs by the oily emollient plays an important part in the action of these remedies, and it seems probable that in many cases equally good results would follow the application of the emollient without any active ingredient.

The emollient ointments are also applied to wounds and mucous membranes as protectives and also as vehicles for other remedies. Here they have a more lasting effect than watery applications, which are more readily absorbed. Emollients are seldom applied to the mouth because of their unpleasant oily taste, but the eye, nose, urethra, vagina and rectum are often treated with them.

Preparations.

Adeps (U. S. P., B. P.), lard; the prepared internal fat of the abdomen of the pig, purified by washing in water, melting and straining.

Adeps Benzoinatus (U. S. P.), *Adeps Benzoatus* (B. P.), benzoinated lard, is prepared from lard by the addition of benzoin, which is believed to preserve it from becoming rancid, and certainly conceals the odor.

Unguentum (U. S. P.), ointment, is a mixture of lard and white wax, and is the basis of many other ointments.

Unguentum Diachylon (U. S. P.) is formed from lead plaster and petrolate perfumed with oil of lavender. The lead is inert, the action being identical with that of ordinary ointment.

Lard contains the ordinary constituents of animal fats, stearin, palmitin, and olein and is seldom used alone, but forms the basis of numerous ointments.

Adeps Lanæ Hydrosus (U. S. P., B. P.), hydrous wool-fat, lanolin, the purified fat of sheep-wool, mixed with not more than 30 per cent. of water.

Adeps Lanæ (U. S. P., B. P.), wool-fat without water.

Unguentum Lanæ Compositum (B. P.), containing lard, wool-fat and paraffins.

Wool-fat has been used extensively in medicine only in the last few years. It consists of cholesterin esters with some impurities, does not become rancid, and differs from the older fats also in being miscible in twice its weight of water without losing its ointment consistency. Lanolin is very often used as an emollient application, as well as to form a basis for more active drugs. The unhydrated wool fat is too sticky to be satisfactory. The hydrated form is generally too hard to be used as an ointment and is therefore diluted with soft paraffin (3 parts) or olive oil (equal parts).

Petrolates or **Paraffins.** When the more volatile constituents of petroleum are distilled off, there remains a number of higher hydrocarbons, chiefly of the marsh gas series, which are used in medicine as emollients. The lower of these hydrocarbons are fluid at ordinary temperatures and are known as *Petrolatum Liquidum* (U. S. P.), *Paraffinum Liquidum* (B. P.), a colorless, oily transparent liquid without odor or taste. When these are removed there remains

Petrolatum (U. S. P.) and Petrolatum album (U. S. P.), Paraffinum molle (B. P.), soft petrolate, vaselin, which has the consistency of an ointment, is yellow or white in color, and is liquefied a few degrees above the temperature of the blood. When the distillation is carried further, the residue is solid at ordinary temperatures, and is known as

Paraffinum (U. S. P.), *Paraffinum Durum* (B. P.), or hard paraffin, which melts at a somewhat higher temperature than vaselin.

Soft petrolate is more extensively used than the others as an emollient and as a basis for ointments, and has the advantage over the older lard that it does not become rancid; as a general rule it is too soft but may be made of the proper consistency by the addition of wool-fat or of starch or zinc oxide (equal parts); or the *Unguentum Paraffini* (B. P.), containing hard and soft paraffin and beeswax, may be employed. Liquid petrolate has been used to dissolve irritant substances for subcutaneous injection, as less pain is caused than when water is used.

Several **Oils** are also used as emollients.

Oleum Olivæ (U. S. P., B. P.), olive oil, a fixed oil obtained from the ripe fruit of the olive, Olea europæa.

Oleum Amygdalæ Expressum (U. S. P.), *Oleum Amygdalæ* (B. P.), a fixed oil expressed from bitter or sweet almonds. It is to be distinguished from the volatile oil obtained from the bitter almonds. The fixed oil contains no prussic acid.

Unguentum Aquæ Rosæ (U. S. P., B. P.), cold cream, is formed of white wax, oil of almonds, and some borax, scented with rose water.

Oleum Gossypii Seminis (U. S. P.), Cotton-seed oil.

These all resemble each other in their composition, and may be used as emollients. Olive oil is generally preferred to the others, but is more expensive, and it is probable that much of the so-called olive oil is really purified cotton-seed oil. Olive oil has been advised as a cholagogue, but has been shown by more exact methods of research to have no effect whatever on the secretion of the bile. It sometimes gives relief in biliary colic and dysentery and in some gastric disorders accompanied by pyloric spasm, probably from its acting as a protective to the mucous membrane of the stomach and duodenum and lessening the acid gastric secretion. A wineglassful is given two or three times a day before meals; in these large doses it possesses a high food value.

Wax (*Cera*), spermaceti (*Cetaceum*) and suet (*Sevum*) are of harder consistency than lard, and are added to the other emollients to make them firmer, which is especially desirable in hot climates and in summer.

Glycerinum (U. S. P., B. P.), glycerin, a liquid obtained by the decomposition of animal or vegetable fats or fixed oils, and containing not less than 95 per cent. of absolute glycerin, $C_3H_5(OH)_3$; clear, colorless, of a syrupy consistence, oily to the touch, with a sweet taste and no odor, soluble in water and alcohol.

Glycerin is used as a solvent for a number of other drugs, the preparations being known as *glycerites* (U. S. P.), *glycerines* (B. P.).

Glycerin is somewhat irritant to the unbroken skin, when it is applied in the pure form, and even diluted glycerin causes pain and smarting when it is applied to unprotected surfaces such as cuts or burns, but the pain soon disappears, and glycerin then acts as a protective. The irritation is due to the glycerin abstracting the fluids of the tissues owing to its avidity for water. Glycerin and its preparations are used very extensively as applications to slight wounds, in irritation of the skin and lips from exposure to cold, and in similar

conditions. They are often applied to hard, dry crusts on the skin in order to soften them and permit of their removal. Glycerin is not a disinfectant except in strong solution, in which it probably acts by the withdrawal of water from the microbes.

Along with the emollients, or oily protectives, may be mentioned another class of mechanical agents, the **Dusting Powders.** Any dry, insoluble, fine powder applied to irritated surfaces of the skin, or slight abrasions, will protect these from the air, and from contact with the clothes and other sources of pressure. These powders, at the same time, soak up any secretions, and render the injured spot less liable to bacterial infection, as they form a more or less impermeable crust. Powders used for this purpose should not be absorbed, or, if absorbable, should not induce any toxic effects. Those most commonly employed are the phosphate and carbonate of lime, talc (*Talcum Purificatum*, U. S. P.) (magnesium silicate), Fullers' earth and kaolin (aluminum silicates) and starch.

A large number of powders are used as surgical dressings, most of them being credited with more or less antiseptic power. In many instances, however, their antiseptic action is so slight that it would appear that most of their virtues are due to their mechanical properties, and not to their bactericidal action. Thus it has been shown[1] that kaolin repeatedly applied to the mucous membranes of the nose and throat removes bacteria completely in the course of a few days; this effect is believed to be due to the great adsorptive power of kaolin and is probably elicited by other fine powders.

III. SUGARS AND FLAVORING SUBSTANCES.

Sugars are used in medicine chiefly to disguise preparations of unpleasant taste, and in the small quantities usually employed have little further effect. In large quantities sugars, like other diffusible bodies, act as irritants to the stomach and bowel, and comparatively small quantities of some sugar substances possess an aperient action: this seems to be due to their colloid form, as pure sugar has no such effect, and it is possible that they merely delay the absorption of fluid, and thus cause softer evacuations than would otherwise occur.

Preparations.

Saccharum (U. S. P.), **Saccharum Purificatum** (B. P.), sugar.

Syrupus (U. S. P., B. P.), a concentrated solution of sugar. Syrup is the basis of a large number of medicated syrups of the pharmacopœias. Sugar and syrup are used exclusively to sweeten mixtures and to aid in the suspension of insoluble bodies. In place of ordinary syrup many of the flavored preparations may be used, such as the syrups of citric acid, acacia, almonds, or of the volatile oil group.

[1] *Hekteon* and *Rappoport.* Jour. Am. Med. Assn., 1915, i, p. 1985.

Saccharum Lactis (U. S. P., B. P.), sugar of milk, lactose, is not so sweet as ordinary sugar, and is much less liable to deliquesce, so that it is used largely to give bulk to powders. It has been said to have diuretic properties when given with large quantities of water, and to cause purgation when given in a more concentrated solution. Asses' milk contains more lactose than cows' milk, and has been recommended for its slight aperient action in chronic constipation.

Maltum (U. S. P.), malt, barley grain partially germinated and then dried. *Extractum Malti* (U. S. P.) 15 G. (4 drs.).

Mel, honey, and *Mel Depuratum* (U. S. P., B. P.), or clarified honey, are used to give taste to mixtures, and have a very slight aperient action, so that they may be advised as articles of diet in habitual constipation. Some medicated honeys are used, of which *Mel Rosæ* is included in the U. S. P., *Mel Boracis* in the B. P.

A number of saccharine preparations with a slight aperient effect are ingredients of the preparations of the more powerful purgatives. Thus manna (*Manna* U. S. P.) obtained from the flowering ash, is contained in the Infusum Sennæ Co. U. S. P., and purging Cassia (*Cassiæ Pulpa*, B. P.), tamarinds (*Tamarindus*, B. P.), figs and prunes form constituents of the confection of Senna and other preparations. They are not prescribed alone, but the fruits may be advised as articles of diet where a mild laxative is required. The tamarind pulp may owe its aperient action in part to the presence of tartrates, citrates, malates, and other cathartic salts. (See Saline Cathartics.)

Frequently other flavors are preferred to sugar, which is especially disliked in fever cases, as sweet fluids do not quench the thirst so effectually as acids and bitters. Many of the preparations of the volatile oils and some of the demulcents are used almost exclusively as flavoring agents, and in some both sugar and volatile oil are combined, as in the syrups.

Instead of sugar some artificial compounds have been introduced of late years. **Glusidum** (B.P.), **Benzosulphinidum** (U.S.P.), or **Saccharin**, $C_6H_4\begin{matrix}CO\\SO_2\end{matrix}>NH$, and its sodium salt (*Sodii Benzosulphinidum*, U. S. P.), $C_6H_4\begin{matrix}CO\\SO_2\end{matrix}>NNa$, or soluble saccharin, are the best known of these. Saccharin is a light, white, crystalline powder, soluble in 400 parts of water and in 25 parts of alcohol. It is about 500 times as sweet as sugar, and gives a distinct flavor to 70,000 times its weight of water. It does not taste exactly like sugar, however, there being a distinct flavor besides that of sweetness, and patients generally object to it after a short time. It has been used as a substitute for sugar in diabetes, a disease in which sugar is to be avoided as far as possible. Saccharin in ordinary amounts has no deleterious action on the digestion or after absorption.

Some pharmacopœial preparations are designed to give color to solutions, but are seldom or never prescribed, although they are sometimes added by the pharmacist.

Among these are cochineal (*Coccus*, U. S. P., B. P., *Tinctura Cocci*, B. P.) and saffron.

IV. SIMPLE BITTERS.

This group includes a number of substances which have little in common except their bitter taste and their comparative inactivity in the body. Several alkaloids may be placed in it, *Berberine*, *Buxine*, *Menispermine* and *Canadine*, for, although these are poisonous in very large quantities, they are harmless in those in which they are contained in the preparations used in therapeutics. In addition to these there may be placed in it numerous neutral bodies, possessing an intensely bitter taste, but with little or no further action, such as the *Quassiins*, *Columbin*, and a few weak acids and glucosides.

Pharmacological Action.—These substances, or rather the preparations containing them, are largely used in therapeutics in order to increase the appetite, and their administration is often followed by a distinct improvement in the digestion and an increase in weight.

Alimentary Tract.—These effects are explained by the action of bitter substances in increasing the secretion of gastric juice, which has been shown to occur in man and animals by a number of experiments. This is not, however, through the bitters acting on the gastric mucous membrane directly, for when they are applied through a gastric fistula, they have no specific action on the secretion. Pawlow has shown that the chief factor that determines the activity of the gastric secretion is the odor and taste of food; thus in dogs with œsophageal fistulæ, in which the food swallowed does not pass into the stomach but escapes through a wound in the œsophagus, the taste and odor of food cause a profuse secretion of gastric juice (psychical secretion). Bitters given shortly before a meal sometimes augment this reflex in normal animals but this is more distinct and occurs more often when cachexia is present (Moorhead); this is due to action in the mouth only, for it is seen when the bitter is not swallowed, and is absent when it is passed into the stomach through a fistula. This change in the secretion is accompanied by improved appetite in cachexia, while the hunger contractions of the stomach are arrested by bitter tastes; introduced directly into the stomach, the bitters have little or no effect in therapeutic doses. The action of the bitters is therefore to increase the psychical secretion of gastric juice, possibly because of the contrast offered by the bitter and the pleasant tastes. The inference may be drawn that the therapeutic effects are best elicited when the bitters are given shortly before a meal, and this accords with universal experience. And the use of the bitters is attended with benefit only in cases in which the gastric juice is deficient. The increase of the gastric juice is followed as usual by a more active secretion by the pancreas. In addition, it is to be remembered that the improvement is largely subjective, and that the bitters are capable of producing a considerable impression upon patients, so that the effects may be due in part to suggestion and not to any real action of the drug.

In comparison with their effects on secretion, the other changes induced in the alimentary tract by the bitters are insignificant. They have little or

no effect on the activity of the ferments in themselves, but the tannin and colloids of the usual preparations may retard their action. And they do not affect the growth of bacteria or yeasts. Absorption from the alimentary tract and the movements of the stomach and bowel are not altered by their presence. The salivary secretion is generally augmented by bitter tastes, and some increase in the leucocytes and red cells of the blood is said to occur after their use.

In very large quantities some of the bitters produce effects that are obviously due to their absorption, but these play no part in their therapeutic effects and have seldom or never been elicited in man.

Preparations.

Gentiana (U. S. P.), **Gentianæ Radix** (B. P.), gentian, the root of Gentiana lutea, contains a glucoside, gentiopicrin, and a trace of tannic acid. 1 G. (15 grs.).

Extractum Gentianæ (U. S. P., B. P.). 0.25 G. (4 grs.). B. P., 2–8 grs.

Fluidextractum Gentianæ (U. S. P.). 1.0 mil (15 mins.).

Tinctura Gentianæ Composita (U. S. P., B. P.), containing gentian, bitter orange peel, and cardamom, 4 mils (1 fl. dr.) (½–1 fl. dr. B. P.).

Quassia (U. S. P.), **Quassiæ Lignum** (B. P.), the wood of Picrasma excelsa or of Quassia amara, contains several neutral bitter substances, resembling each other closely chemically and known as quassiins.

Tinctura Quassiæ (U. S. P., B. P.), 2 mils (30 mins.).

Infusum Quassiæ (B. P.), ½–1 fl. oz.

Calumba (U. S P.), **Calumbæ Radix** (B. P.), columbo, the root of Jateorrhiza palmata, or Columba, contains columbin, a neutral body, columbic acid, and three alkaloids, columbamine, jateorrhizine, and palmitine closely resembling berberine.

Tinctura Calumbæ (U. S. P., B. P.), 4 mils (1 dr.).

Many other remedies have been used in medicine, which owe their reputations to their bitterness only. As a general rule they have been introduced as possessing specific properties in some such disease as gastric cancer, but have failed to maintain their promise and gradually are recognized to be in no way superior to gentian and other established bitters. Their use as bitters often forms a prelude to their complete abandonment. Among these unnecessary bitter drugs may be mentioned *Taraxacum*, the root of the dandelion; *Chirata*, the plant Swertia chirata, containing a glycoside and ophelic acid; *Berberis*, the rhizome and roots of the barberry, containing the alkaloid berberine; *Pareira*, the root of Chondrodendron tomentosum, containing two alkaloids, bebeerine and chondrodine; *Serpentaria*, snakeroot, the rhizome and roots of two species of Aristolochia, containing an unknown bitter principle and an alkaloid, aristolochine, and *Humulus*, hops, with its preparation *Lupulin*, a glandular powder which contains a bitter neutral principle, an acid and resins. These still receive recognition in the pharmacopœias, if not in practical therapeutics. Others, which have reached a further stage on the path to oblivion, but which are still heard of occasionally are *Cusparia* (Angostura bark), *Nectandræ Cortex* (Bebeeru bark), *Condurango* (Marsdenia Condurango) and *Coto*.

Instead of the simple bitters, cinchona and nux vomica preparations are often used in small quantities. Many of the preparations which will be enumerated under the volatile oil series owe much of their effect to the bitter which accompanies the volatile oil, and in numerous other pharmacopœial preparations bitters are present, although their effect is hidden by the action of the drug in other directions.

Therapeutic Uses.—The bitters are used chiefly to increase the appetite and the digestion. In convalescents, in persons of sedentary

habits, and occasionally in chronic dyspeptic conditions they are of value, while in cases of more acute gastric irritability and in hyperacidity they may do harm rather than good. Gentian, Quassia and Calumba are the only simple bitters that are largely used, and the first is much the most important. They are generally prescribed as tinctures, fluid extracts or other fluid preparations. The last two may be prescribed with iron preparations, as they contain little or no tannic acid and thus cause no precipitate. Pills are sometimes prescribed with extract of gentian or quassia, but it seems open to question whether these ingredients have really any effect when given in this form, as the bitter taste, on which their action depends, is largely concealed. Compound tincture of gentian is sometimes used to give flavor rather than for any effect on the digestion. Quassia infusion (10 per cent.) is injected as an enema in the round worms of children.

Several of the drugs mentioned, such as taraxacum and gentian, have been supposed to have a specific action on the liver, but there are no sufficient grounds for this belief. The supposed virtues of pareira as a diuretic and of berberine, buxine, and other alkaloids as substitutes for quinine in malaria have also proved to have no foundation, and the popular reputation of hops as a narcotic probably arises from its association with alcohol in beer. Cotoin and Coto bark are said to have some special effect in lessening diarrhœa, in addition to their action as bitters.

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Pepper Group.

The pepper group comprises a few drugs which are used for their effect on digestion but which have a much more pungent taste than the bitters, and cause marked irritation when they are applied in large doses. They thus stand midway between the simple bitters and the carminative volatile oils, and are sometimes known as aromatic stomachics.

Black Pepper contains a weakly basic substance, *Piperine* (which is broken up by caustic alkalies into *Piperidine* and *Piperinic acid*), in addition to a volatile oil and a bitter pungent resin. Piperine is insoluble in water, and has therefore no taste when absolutely pure, but is hot and pungent to the taste when it is taken in solution.

Pyrethrum, or pellitory, contains similar constituents but is scarcely used except as an ingredient of insect powders.

Capsicum, or Cayenne pepper, contains *Capsaicin*, a neutral body with a hot pungent taste.

Many other plants contain irritant principles which have been employed as stomachics. Thus the use of mustard as a condiment depends on its forming irritant sulphur compounds, but mustard is used in medicine only as a skin irritant and will be discussed under that heading.

Pepper and capsicum are largely used as condiments, and are comparatively seldom prescribed in therapeutics. Both are used in domestic medicine as skin irritants, and capsicum is prescribed where a strong stomachic irritant is required. The tincture has been employed in chronic alcoholism in order to provide a substitute for the local irritant effects of spirits in the stomach.

Piper Methisticum, or Kava Kava, is used in the South Sea Islands to prepare an intoxicating liquor, which according to Kesteven, differs from the alcoholic preparations in producing marked muscular weakness without affecting the mental powers. Other observers state, however, that it causes confusion and sleep very much as alcohol does. Its local action resembles that of pepper, and like it, it has been advised in gonorrhœa. Its virtues seem to reside in two resinous bodies.

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V. DIGESTIVE FERMENTS.

A number of digestive ferments have been introduced into therapeutics for the treatment of gastric and intestinal disorders. The earlier members of the series were proteolytic ferments, intended to reinforce the pepsin of the stomach, but of recent years the amylolytic ferments have also been strongly advocated.

1. Pepsin.

The pharmacopœial preparations of pepsin are generally obtained from the pig's stomach. It digests only in acid solution, the best results being obtained in a solution of 0.2 per cent. of hydrochloric acid. In alkaline solution it is inert, and in fact is rapidly decomposed, so that when pepsin and alkaline carbonates or bicarbonates are prescribed together, the effects are due to the alkalies only.

Pepsin is used in therapeutics on the theory that the stomach does not secrete enough of the ferment in certain conditions. But it may be questioned whether this is true in even a small proportion of the cases treated with pepsin, for the gastric juice is almost always capable of digesting proteins if it is acid in reaction. In a number of forms of dyspepsia the acid secretion is insufficient, but the ferment is almost always present in quantity, for it digests proteins outside the body as soon as it is acidulated. Pepsin is indicated then only in the rare cases in which the contents of the stomach acidulated with hydrochloric acid fail to digest proteins. It is very often administered in

other forms of dyspepsia, and certainly does no harm, but there is no question that it is entirely unnecessary in the great majority of the cases in which it is prescribed.

Preparations.

Pepsinum (U. S. P., B. P.), a proteolytic ferment obtained from the glandular layer of fresh stomachs from healthy pigs, and capable of digesting not less than 3,000 times its own weight of freshly coagulated egg albumin.[1] It is a fine, white, amorphous powder or thin scales, free from offensive odor and having a mildly acid or saline taste, usually followed by a suggestion of bitterness. 0.5 G. (8 grs.), in powder, or in solution in 0.2 per cent. hydrochloric acid.

Pepsin is generally given during or after meals. As has been stated, it is very rarely indicated, as the gastric juice almost always contains sufficient ferment.

Glycerinum Pepsini (B. P.) contains hydrochloric acid. A fluid drachm represents 5 grs. of pepsin. 1–2 fl. drs.

Many other preparations of pepsin are used in popular medicine, to a less extent by the profession. Pepsin wines, for example, are often taken as tonics and digestives, but have only the effects of alcoholic beverages.

2. Pancreatic Ferments.

The pancreatic ferments have also been introduced into therapeutics, generally in the form of an extract of the gland, *pancreatin*. These ferments differ from pepsin in acting only in alkaline or neutral solution, and besides digesting proteins, form sugar from starch and saponify and emulsify fats. The pancreatic ferments are rendered inert by a comparatively short exposure to the acid gastric juice.

The value of pancreatin is even more problematical than that of pepsin, for though it would no doubt be valuable where the digestive ferments, particularly those of the pancreas, were deficient, this has not been shown to occur. On the other hand, the pancreatic ferments are certainly destroyed in passing through the stomach. It has been suggested, however, that they may act in the stomach, if they are given before or with the food, as the acid gastric juice is only secreted slowly, and some time must elapse before the pancreatin is rendered inert. Attempts have been made to preserve the pancreatin from the deleterious effects of the gastric juice by administering it in capsules which are dissolved only in the intestine. It is certainly possible that the pancreatin may be useful in certain cases, where the ferments of the pancreas are absent and the acid of the stomach so deficient as not to be destructive, but there is no reason to suppose that this series of accidents occurs at all frequently, and it is impossible to diagnose inefficiency of the pancreatic secretion. Pancreatin is now used chiefly to digest the food before it is taken, about 5 grains sufficing for a pint of milk. It has been applied to cancerous tumors in the hope of destroying the malignant tissue, but has not proved of value.

[1] The B. P. preparation may be obtained from the pig, sheep or calf and is required to digest 2500 times its weight of hard-boiled white of egg.

Preparations.

Pancreatinum (U. S. P.), a mixture of the enzymes naturally existing in the pancreas of warm-blooded animals, usually obtained from the fresh pancreas of the pig. It forms a yellowish, yellowish-white, or grayish, amorphous powder, having a faint, not disagreeable odor and a meat-like taste, and is slowly soluble in water. 0.5 G. (8 grs.), in powder or in capsules. Keratin capsules have been proposed in order to protect the pancreatin from the gastric juice.

Liquor Pancreatis (B. P.), a liquid preparation containing the digestive principles of the fresh pancreas of the pig. Three cubic centimeters of the solution ought to digest 80 c.c. of milk. Predigested milk is prepared by diluting 400 c.c. of fresh milk with 100 c.c. of water, heating to 40° C. and adding 15 c.c. of liquor pancreatis with a gram of sodium bicarbonate; the whole is kept warm for an hour and then heated to 70° to destroy the ferments.

3. Vegetable Ferments.

Besides these animal digestive ferments, a number of vegetable proteolytic enzymes are known, and have enjoyed a more or less short-lived popularity. Probably many more plant juices are able to digest proteins than are at present generally recognized; thus many of the bacteria liquefy gelatin and albumin, and the insectivorous plants, such as Drosera (sundew) and Dionea, secrete a digestive fluid. Figs, pine-apple (*bromelin*), the scarlet pimpernel (Anagallis arvensis), and many others of the higher plants have been shown to possess these ferments, but the best known of these is the Carica papaya, or pawpaw, which contains a digestive ferment known as *papain*, *papayotin*, or *papoid*. This ferment acts in neutral, slightly acid, or alkaline solution at the temperature of the body and in the cold. It has been used instead of pancreatin and pepsin in disorders of the digestion, and also as an anthelmintic. Diphtheritic membranes have been treated by the frequent application of papain solution; the underlying disease was not favorably influenced, however, and the treatment has been abandoned. Papain solution has also been injected by the hypodermic needle into tumors and abscesses, with the intention of digesting the new growth, or accelerating the progress of the abscess toward the surface, but the results obtained do not encourage its further use. Peptones are unquestionably formed in the tumors when papain is injected.

Several milk-curdling ferments have been found in plants, but none of them have been used in therapeutics.

4. Diastase.

Several amylolytic or sugar-forming ferments have been used more or less in therapeutics, the first of these being the *diastase* or *enzyme of malt*, which is known under the names of malt extract, maltzyme, (*Diastasum*, U. S. P.). When grain is allowed to germinate, its starch is formed into a soluble form (sugar) by means of a ferment known as diastase, and it was supposed that this diastase might aid the digestion of starchy foods in the body. When malt extract is formed at a low temperature, it unquestionably contains diastase and is capable of digesting starch, but many of the extracts on the market are quite inert, the ferment having been destroyed by heat. Those extracts are therefore devoid of digestive power, but form a pleasant, easily digested food. They often contain alcohol, and are then indistinguishable from beer or stout. More recently, some other sugar-forming ferments have been brought

forward, notably *Taka-diastase* obtained from Eurotium oryzæ, a mould of the aspergillus family; it has been recommended in cases in which there is supposed to be a deficient digestion of starch. It ceases to act in the gastric juice as soon as the acidity exceeds 0.1 per cent., but may be able to digest a certain amount of starch in the mouth and stomach before it is destroyed. The question at once arises, however, whether the ordinary digestive juices are ever unable to digest the starch of the food. And although a new term, "amylaceous dyspepsia," has been introduced to indicate this class of cases, if they should be found to exist, it must be admitted that no satisfactory evidence of their existence has been brought forward as yet. It is stated that more starch is found to be digested in the stomach after the administration of diastase, but this seems to be beside the point, for it merely indicates that less starch reaches the intestine for the pancreatic juice to act upon. Until it is shown that in some cases the digestion of starch by the intestinal ferments is insufficiently performed, the diastase preparations would seem to be superfluous.

VI. VOLATILE OIL SERIES.

The group of volatile, ethereal, or essential oils contains a large number of preparations in the pharmacopœias of all countries. These oils are obtained from plants by distillation, or more rarely by pressure, and must be distinguished by the student from the fatty or fixed oils, which are non-volatile. The volatile or ethereal oils are found chiefly in the fruits and flowering parts of plants, and are very widely diffused through the vegetable kingdom, though some orders, such as the Labiatæ, Umbelliferæ, Aurantiaceæ, Cruciferæ, and Coniferæ, are pre-eminent in their production. They are all strongly odorous, and are therefore used in perfumery, and to conceal nauseous odors and tastes in medicine.

Their composition is extremely variable. The commonest constituents are *Terpenes*, and some oils contain these only, while in a few oils no terpene has been found (Attar of Roses). Terpenes are hydrocarbons of the aromatic series, and possess the general formula $(C_5H_8)_n$. The great majority of them, or the terpenes proper ($C_{10}H_{16}$), are combinations of a dihydrobenzene with propyl and methyl ($C_6H_4(H_2)C_3H_7CH_3$). Some twelve terpenes of this formula are known, varying in their chemical structure and in their stereometrical form. Another group of these hydrocarbons is formed by the *Sesquiterpenes* ($C_{15}H_{24}$), while a few *Diterpenes* ($C_{20}H_{32}$) are known. Some volatile oils consist of these hydrocarbons only, but most of them contain in addition some oxidized aromatic substances, such as phenols, ketones, aldehydes, acids, and their compounds; as instances of these may be cited camphor, thujon (from oil of absinthe), sabinol (oil of savine), safrol, thymol, eucalyptol, myristicin and vanillin. Many of these oxidized products crystallize out when the volatile oil is cooled sufficiently, and especially on long standing, and the resulting solid is known as a *Stearoptene*, while the fluid remaining is sometimes called *Elæoptene*. The oils containing oxygen are not so volatile as the pure hydrocarbons, but the odor is often due chiefly to the oxidized substances. A very few oils contain nitrogenous bodies, generally in the form of cyanides, while, on the other hand, the majority of the volatile oils of the Cruciferæ contain sulphur bodies which lend them a pungent disagreeable odor, quite different from that of the other oils.

The volatile oils are generally clear, colorless fluids, although some of them are green or blue in color. After long keeping they often acquire a yellowish color and an acid reaction, from the formation of resins. They are generally light, sparkling fluids, but the oils of copaiba and cubebs are more viscid. They are insoluble in water except in very small amount, which, however, is enough to lend their characteristic odor to the solution; in strong alcohol, ether, benzene, chloroform, and fixed oils, they are freely soluble.

Many of the plants from which the volatile oils are obtained possess other active constituents, such as bitters, and as many of the preparations used in therapeutics are formed, not from the distilled oils, but from the crude parts of plants, it must be noted that the oil is not the only active principle in them.

Action Externally.—The volatile oils all possess antiseptic properties, which are doubtless due in part to their volatility and their solubility in lipoids enabling them to penetrate readily into protoplasm. Many of them appear to be more germicidal than carbolic acid in favorable circumstances, but they are generally too insoluble in water to be employed easily in surgery.

Applied to the skin, they cause redness, itching and warmth, owing to a local dilatation of the vessels, which may be due to the penetration of the oil to the cutaneous arterioles or veins, or to a local reflex from the irritated terminations of the sensory nerves. When painted on the mucous membranes, such as those of the eye or nose, or on wounds, the volatile oils cause similar irritation, which is betrayed by redness and congestion, pain and smarting.

Action on the Alimentary Canal.—Strong solutions of the oils have generally a hot, burning taste, and if kept in the mouth, cause redness and irritation of the mucous membranes, although some of them induce a sense of coolness at first. At the same time the organs of smell are affected by these oils, which are almost all possessed of characteristic odors. The irritation of the mouth leads to a reflex secretion of saliva, which is often very profuse. The antiseptic action of the oils is exercised in the mouth as elsewhere, and may have a beneficial effect in some conditions.

On passing into the stomach, the oils cause the same sensation of warmth in the gullet, and this is accompanied by a sense of well-being and comfort, the appetite is often increased, and any feeling of distention after meals is relieved. This is often attended by the eructation of quantities of gas. Substances which produce these effects in the stomach are known as *carminatives*, and many explanations of their action have been offered. The antiseptic action may occasionally play a part in the carminative action, and possibly the secretion may be encouraged by the slight irritation and by the agreeable odor and taste; the activity of the ferments is rather retarded than augmented. The movements and tone of the stomach are decreased by small quantities of the oils applied to the mucous membrane; this weakening action probably extends to the sphincters, and their relaxation may explain the relief of the feeling of

distention and the eructation of gas from the stomach after the administration of these oils. In the intestine small quantities generally increase the movements, while larger ones decrease them; sometimes the bowel is relaxed owing to a reflex arising from the action on the stomach. In practice they often relieve intestinal flatulence and distention and lessen the spasms which cause colic. Small quantities are incorporated in the preparations of the more powerful purgatives to lessen the pain and griping which these are liable to induce.

An indirect effect of the local action on the gullet and stomach is slight flushing of the skin from dilation of its vessels, along with a feeling of warmth and relief of chill. This appears to arise from a reflex travelling from the sensory ends in the mucous membranes to the vasomotor centre in the medulla oblongata and is most frequently seen under camphor.

Excretion.—Many of the terpenes are oxidized to phenols in the body and are then excreted in the urine, for the most part in combination with glycuronic or sulphuric acid. Traces pass out in the expired air and impart an odor to the breath. The urine also contains some in a free form and may thus smell of the original oil or of some of its derivatives. Some of the constituents of the oils are oxidized to acids and excreted in the urine as salts.

In the course of excretion, some of the oils cause irritation of the lungs and kidneys, so that some of them are employed to increase the bronchial secretion, while others have a distinct diuretic action. This irritant action is of course not confined to the tissue, but extends to microbial guests, so that some of the volatile oils are given internally almost exclusively for their antiseptic action in the urine.

Poisoning.—The various oils differ a good deal in their activity while resembling each other closely in the general characters of their effects. All of them may produce marked irritation of the stomach and bowel when given in large quantities, but the oils of tansy, sage, and English pennyroyal are distinguished especially by the violent inflammation they cause, and by the frequency with which fatal poisoning occurs from their use. The symptoms are those of acute gastric, intestinal, and often renal irritation—vomiting, purging, acute pain in the abdomen, blood in the stools and in the vomited matter, collapse, weakness of the pulse and respiration, anuria, or albumin and blood in the urine, and convulsive attacks ending in coma and death. Great hyperæmia of the abdominal organs, often blood in the peritoneal cavity, and sometimes acute inflammation of the kidney are the chief post-mortem appearances. Though they do not increase the uterine movements directly, the congestion of the organs of the abdomen may cause abortion in pregnancy, or increase the menses, and in most cases of poisoning, these oils have been taken to induce abortion; too often they have proved fatal without this end being achieved.

General Action.—The small quantities of volatile oils administered in ordinary medicinal use pass through the tissues without modifying them percept-

ibly, their only effects arising in the organs by which they are absorbed and excreted. In large quantities, however, some of them (the oils of wormwood, nutmeg, sage, savine among others) produce symptoms from a direct action on the central nervous system, which is first stimulated and then depressed.

The relative importance of these two stages differs in different oils, some, *e. g.*, turpentine oil, causing only a transient excitement, followed by marked weakness and depression, while others, such as the oil of absinth, cause very marked excitement and convulsions. The activity of the oils as nervous poisons also varies greatly, some producing only insignificant effects on the central nervous system compared with those from their local action, while in others, such as the oil of absinth or wormwood, the symptoms from the nervous system predominate in cases of poisoning. As a general rule the higher divisions of the central axis are affected more than the lower, and epileptiform or clonic convulsions may be induced (camphor), or tremors similar to those described under carbolic acid and presumably of similar origin (safrol and nutmeg oil). In many cases a combination of excitement and ataxia is observed, the animal moving about restlessly, but being unable to balance itself. In the later stages of poisoning the spontaneous movements cease, while the excitation of the lower centres still persists, and wild convulsive movements accompany the final arrest of the respiration. The respiratory centre is finally depressed, but this depression is often preceded by stimulation, the breathing increasing both in rapidity and in volume. The vasomotor centre undergoes similar changes, the blood-pressure falling from some oils immediately, from others only after a preliminary increase.

The *heart* does not seem to be affected by most of the volatile oils, except indirectly from the collapse and shock. The frog's heart perfused with Ringer's solution containing a volatile oil is often accelerated, but soon becomes slow and weak.

Involuntary *muscle* suspended in Ringer's solution containing small amounts of volatile oil ceases its rhythmical movements and relaxes, apparently from a direct action of those bodies on the muscle fibre; the same action is seen in the *uterus* suspended in this way.

Some of the constituents of the oils (pulegon, myristicin, safrol) cause fatty degeneration of various organs, especially of the liver and kidney, while others of very similar constitution have no such effect.

Most of the oils are poisonous to the *protozoa* in fairly dilute solutions; as a general rule the movements of these organisms are accelerated by very small quantities of the oils. The protozoa are much more susceptible to the oils than the *bacteria*, some of which continue to live in 5 per cent. solutions.

Although these general effects of the volatile oils have no therapeutic importance, the frequent occurrence of epilepsy and insanity in habitual absinth drinkers and occasional poisoning from others of the series have given them some practical interest.

1. Volatile Oils Used as Flavoring Agents and Carminatives.

As regards their use as flavoring agents but little need be said, one preparation is used by one physician, another by another; and the selection is largely a matter of custom and taste. The orange preparations are probably more generally appreciated by patients than any others. Carminatives are used only when no marked irritation of the stomach or intestine is present, but the gastric juice seems unable to cope with the food, especially in children and in persons of sedentary habits. In cases of colic, flatulence and abdominal distention they are often of use, provided that these are not due to peritonitis and other inflammatory diseases. Several of them have been employed

as surgical antiseptics, but they are more widely used as parasiticides for scabies, pediculi, etc. Some of the oils, such as oil of cloves, are used in dentistry to relieve pain, and also for their antiseptic action; the relief of pain is due to their paralyzing the exposed nerve ends after a preliminary irritation. Eucalyptus has been advised in septic conditions and in malaria but is of no value in these conditions; its chief constituent, eucalyptol ($C_{10}H_{18}O$), is equally devoid of any special virtues to distinguish it from the other volatile oils. Volatile oil preparations are sometimes given internally in the hope that in their excretion through the lungs they will exercise an antiseptic action in pulmonary disease, but the traces excreted in this way are quite incapable of any noticeable effect on microbial growth, and the tubercle bacillus, against which these measures are most frequently directed, appears to be peculiarly resistant to the action of this group of remedies. They are frequently inhaled with a similar object. Some of them have been used as anthelmintics to destroy tapeworm in the intestine, and thymol has recently proved very effective in destroying the intestinal parasites in uncinariasis (see Thymol). Externally some of them are used as mild skin-irritants, generally in the form of spirits. Arnica has a great popular reputation as a stimulating local remedy in bruises and sprains, although it has no specific action and is in no way preferable to the other members of the series.

The volatile oils are largely used as flavors in cookery and sweet-making, and are important constituents of many of the popular liqueurs, and therefore have a certain dietetic importance.

Preparations.

Crude Drugs.—Many of the pharmacopœial preparations are whole plants, seeds, leaves, or flowers, and are never prescribed, although some of them are used in popular medicine in the form of infusions or "teas." The virtues of these old-fashioned remedies lie perhaps more in the large draughts of warm water than in the traces of volatile oil which they contain, but the presence of the latter prevents, to some extent, the nausea produced by warm water alone. These infusions are used to induce perspiration in fevers or chills, as diuretics, or to relieve colic and griping, and generally contain about a tablespoonful of the herb to one or two cupfuls of water. Those most frequently used for this purpose are peppermint and spearmint leaves and tops (*Mentha Piperita* and *Mentha Viridis*, U. S. P.); Coriander seeds (*Coriandrum*, U. S. P., *Coriandri Fructus*, B. P.); Chamomile flowers (*Matricaria*, U. S. P.); Anise (*Anisum*, U. S. P., the fruit of Pimpinella anisum); Elder-flower and Horehound. In different countries, however, the constituents of the herbalist recipes vary according to the local flora. The U. S. Pharmacopœia recognizes a number of other crude drugs of this group, but as these are seldom or never prescribed, they need only be enumerated here: *Rosa Gallica* (red rose petals), *Eucalyptus*, *Limonis Cortex* (lemon peel), *Aurantii Dulcis Cortex*, *Aurantii Amari Cortex* (sweet and bitter orange peel), *Caryophyllus* (cloves), *Cinnamomum* (cinnamon), *Sassafras* (sassafras bark), *Fœniculum* (fennel), *Cardamomi Semen* (cardamom), *Carum* (caraway), *Myristica* (nutmeg), *Arnica*, and *Zingiber* (ginger). The British Pharmacopœia is less lavishly supplied with these little used crude drugs. It contains *Coriandri Fructus* (coriander seeds), *Aurantii Cortex Recens* and *Siccatus* (fresh and dried

orange peel), *Cinnamomi Cortex* (cinnamon bark), *Cardamomi Semina* (cardamom seeds), and *Zingiber* (ginger).

Bitter Almonds (Amygdala Amara, B. P.) may be mentioned here, as, although they contain no volatile oil in themselves, one is formed from them when they are bruised in water. They contain a glucoside, amygdalin, and a ferment, emulsin, which, in the presence of water, decomposes the amygdalin into dextrose, prussic acid, and benzaldehyde.

Amygdalin.			Dextrose.	Prussic acid.	Benzaldehyde.	
$C_{20}H_{27}NO_{11}$	+ $3H_2O$	=	$2(C_6H_{12}O_6)$	+ HCN	+ C_7H_6O	+ H_2O

The prussic acid and benzaldehyde, which are probably in combination and not merely mixed together, are known as the oil of bitter almonds, which is much more poisonous than the other volatile oils, owing to its containing prussic acid. Emulsin is also contained in the sweet almond, but no amygdalin, so that no prussic acid is formed when it is pounded in water. The fixed oil of almonds is formed from bitter and sweet almonds, but contains no prussic acid. Laurel leaves, and the bark of the Virginian prune, or cherry (*Prunus Virginiana*, U. S. P., *Pruni Virginianæ Cortex*, B. P.), also contain amygdalin, or some nearly related substance, and emulsin, and form benzaldehyde and prussic acid when rubbed up with water. The Virginian cherry bark has, however, a more bitter taste than the others, from the presence of a resin or some other unknown body.

The **Volatile Oils** themselves are also represented in unnecessarily large numbers in the pharmacopœias.

U. S. P.—*Oleum Menthæ Piperitæ* (oil of peppermint), *Ol. Menthæ Viridis* (spearmint), *Ol. Lavandulæ* (lavender), *Ol. Eucalypti* (eucalyptus), *Ol. Limonis* (lemon), *Ol. Aurantii* (orange), *Oleoresina Zingiberis* (ginger), *Ol. Amygdalæ Amaræ* (bitter almonds), *Ol. Caryophylli* (cloves), *Ol. Pimentæ* (allspice), *Ol. Cari* (caraway), *Ol. Cassiæ* (cinnamon), *Ol. Coriandri* (coriander), *Ol. Cajuputi* (cajuput), *Ol. Sassafras* (sassafras), *Ol. Anisi* (anise), *Ol. Fœniculi* (fennel), *Ol. Rosmarini* (rosemary), *Ol. Juniperi* (juniper), *Ol. Thymi* (thyme), *Ol. Myristicæ* (nutmeg). Dose 0.2 mil (3 mins.).

B. P.—*Oleum Anethi* (oil of dill), *Ol. Anisi* (anise), *Ol. Cajuputi* (cajuput), *Ol. Carui* (caraway), *Ol. Caryophylli* (cloves), *Ol. Cinnamomi* (cinnamon), *Ol. Coriandri* (coriander), *Ol. Eucalypti* (eucalyptus), *Ol. Lavandulæ* (lavender), *Ol. Limonis* (lemon), *Ol. Menthæ Piperitæ* (peppermint), *Ol. Myristicæ* (nutmeg), *Ol. Rosmarini* (rosemary). Dose ½–3 mins.

The majority of these oils resemble each other very closely in their effects and require no special comment. The oils of rosemary, juniper, and savine are more irritant than the others, and are seldom used. The oils of wintergreen and of birch consist mainly of methyl-salicylate, and may be used instead of the other salicylates. Nutmeg and mace oils are more poisonous than the others, not from their local irritant action so much as from their effects after absorption. Oil of bitter almonds contains a very variable amount of prussic acid and therefore cannot be substituted for the other volatile oils, but its preparations are so dilute as to be devoid of all danger.

The volatile oils themselves are comparatively little used. A single drop may be added to powders, pills or solutions to give a pleasant odor, and their presence in tooth powders renders these more or less strongly antiseptic. Occasionally they are given in cases of colic or in chill by pouring a few drops on a piece of sugar which is sucked.

Spiritus are formed from many of the volatile oils by dissolving them in alcohol, sometimes with the addition of water and sometimes with some of the crude drugs, so that the preparation is really a mixture of tincture and spirit. The spirits or essences of the volatile oils are

used very largely as flavoring agents in mixtures for internal use, and are often added to external applications to lend them odor. They may also be prescribed where alcohol is indicated but is distasteful to the patient; the spirits of the volatile oils contain nearly double the amount of alcohol in brandy, and have to be diluted accordingly. Any of them may be used as carminatives, but the spirits of peppermint, cinnamon, anise and lavender are more frequently used for this purpose than the others. Another useful carminative preparation is the compound tincture of camphor, which contains camphor and several volatile oils along with a small amount of opium; the last aids the real carminatives in relieving the discomfort by its action after absorption.

Spirit of juniper is often given as a diuretic, either alone or along with other drugs. Spirit of rosemary is generally used externally. Many of the common perfumes are spirits of different volatile oils; thus eau de Cologne contains the oils of bergamot, lemon, rosemary, lavender and orange-flower, along with acetic ether and alcohol.

The dose of the spiritus as carminatives is 2–4 mils (30–60 mins.) They are often prescribed along with other stomachics, such as nux vomica, cinchona, or the bitters.

U. S. P.—*Spiritus Amygdalæ Amaræ, Spir. Anisi, Spir. Aurantii Compositus* (containing the oils of orange peel, lemon, coriander, and anise), *Spir. Cinnamomi, Spir. Juniperi, Spir. Juniperi Compositus* (containing oils of juniper, caraway, and fennel; 8 mils (2 fl. drs.). *Spir. Lavandulæ, Spir. Menthæ Piperitæ, Spir. Menthæ Viridis.*

Elixir Aromaticum and *Elixir Glycyrrhizæ* are preparations of the Spir. Aurantii Compositus, which are used exclusively as flavors.

B. P.—*Spiritus Anisi, Sp. Cajuputi, Sp. Cinnamomi, Sp. Juniperi, Sp. Lavandulæ, Sp. Menthæ Piperitæ, Sp. Myristicæ, Sp. Rosmarini.*

Aquæ.—The volatile oils are very insoluble in water, but when they are shaken in it, enough remains in the water to give it the odor and taste of the oil. In the process of obtaining the oils from the crude drugs by distillation, some oil is held by the water, and a number of these waters (aquæ) are contained in the pharmacopœias. They are used as substitutes for distilled water in making up prescriptions, the small quantity of volatile oil serving merely to give a pleasant odor and taste.

U. S. P.—*Aqua Anisi, Aq. Aurantii Flor.* and *Aq. Aurantii Florum Fortior* (the latter containing twice as much volatile oil as the former), *Aq. Cinnamomi, Aq. Fœniculi, Aq. Menth. Piperitæ, Aq. Menth. Viridis, Aq. Amygdalæ Amaræ, Aq. Rosæ, Aq. Rosæ Fortior* (the latter twice as strong as the other.

B. P.—*Aqua Anethi, Aq. Anisi, Aq. Aurantii Floris, Aq. Cinnamomi, Aq. Menthæ Piperitæ, Aq. Rosæ.*

Some of the preparations containing volatile oils are derived not from the oil itself, but from the crude drug, and therefore contain non-volatile substances which are generally absent from the prepara-

tions already mentioned. As a general rule these non-volatile bodies are inactive, but in some cases, bitters or resins are contained in the preparations, and may influence their action. Thus a bitter glucoside, hesperidin, is found in the orange peel, and is present in the preparations formed directly from it, while it is absent from those formed from the volatile oil. Ginger contains a resin of hot, burning taste, which increases the carminative action of the oil. Cinnamon contains some tannic acid, which passes over in the tincture, while a fixed oil is contained in cardamom.

Among the preparations formed from the crude drugs are the **Syrups**, which are used exclusively as flavoring agents.

U. S. P.—*Syrupus Aurantii Florum, Syr. Aurantii, Syr. Zingiberis, Syr. Pruni Virginianæ, Syrupus Tolutanus.* Dose, 4–16 mils (1–4 fl. drs.).

B. P.—*Syrupus Aromaticus* (containing tincture of orange and cinnamon water), *Syr. Aurantii, Syr. Aurantii Floris, Syr. Limonis, Syr. Pruni Virginianæ, Syrupus Zingiberis, Syrupus Tolutanus.* Dose, 2–4 mils (½–1 fl. dr.).

The **Tinctures** are used for the same purposes as the spirits of the pure oils, and in the same dose, 1–4 mils (15–60 mins.).

U. S. P.—*Tinct. Aurantii Amari, Tinct. Aurantii Dulcis, Tinct. Limonis Corticis, Tinct. Cardamomi Composita* (containing cardamom, cinnamon, caraway), *Tinct. Cinnamomi, Tinct. Lavandulæ Composita* (oils of lavender, rosemary, cinnamon, cloves, nutmeg), *Tinct. Zingiberis.*

B. P.—*Tinct. Aurantii, Tinct. Cardamomi Composita* (containing cardamom, caraway, cinnamon), *Tinct. Cinnamomi, Tinct. Lavandulæ Composita* (lavender, rosemary, cinnamon, nutmeg), *Tinct. Limonis, Tinct. Pruni Virginianæ, Tinct. Zingiberis.*

Fluidextracts of the volatile oil series.

U. S. P.—*Fluidextractum Aurantii Amari,* 1 mil (15 mins.).

Fluidextractum Zingiberis, 1 mil (15 mins.).

Fluidextractum Aromaticum, 1 mil (15 mins.), from aromatic powder.

Other Preparations.

Pulvis Aromaticus (U. S. P.) contains cinnamon, cardamom, ginger, and nutmeg in powder, and is a useful carminative in doses of 1 G. (15 grs.).

Pulvis Cinnamomi Compositus (B. P.) contains cinnamon, cardamom and ginger, and is used as a carminative in doses of 10–60 grs.

Pure Principles used as flavors:

Methylis Salicylas (U. S. P., B. P.) is formed synthetically or obtained from oil of wintergreen or oil of birch and is a colorless or yellowish liquid with a pleasant characteristic taste. Dose 0.75 mil. (12 mins.).

Vanillinum (U. S. P.), vanillin ($C_6H_3 \cdot OH \cdot OCH_3 \cdot COH$), occurs in vanilla and is also made synthetically. It forms white needle crystals, slightly soluble in water, easily soluble in alcohol and ether, and possesses the odor and taste of vanilla. Dose, 0.03 G. (½ gr.).

Benzaldehydum (U. S. P.), benzaldehyde (C_6H_5COH), occurs in the oil of bitter almonds, and is also made artificially. It is a colorless fluid with the odor and taste of bitter almond oil, very slightly soluble in water, but freely miscible with alcohol. Dose, 0.03 mil (½ min.).

Eugenol (U. S. P.), a phenol ($C_6H_3OH \cdot OCH_3 \cdot C_3H_5$) obtained from oil of cloves and other oils, and forming a colorless liquid with an odor like cloves, and a hot, burning taste. Dose, 0.2 mil (3 mins.).

These principles are used exclusively to give flavor and color.

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2. Camphor.

Some of the volatile oils deposit crystalline substances or stearoptenes after standing for some time, especially when they are exposed to cold. As a general rule these bodies are present in only small amount, and have not been investigated apart from the volatile oils, of which they form constituents; but a few of them have attracted attention in therapeutics, not only on account of their local effects, which resemble those elicited by the volatile oils in general, but also because of their action in the tissues after absorption. The chief of these is **Camphor**, which has been used in Chinese medicine for many centuries, and which has also played a considerable rôle in Western therapeutics. It is derived from the Cinnamomum camphora of China and Japan, and possesses the formula $C_{10}H_{16}O$, differing from the terpenes in possessing a ketone (=CO) link.

Another body closely resembling ordinary camphor is **Borneol** or Borneocamphor ($C_{10}H_{18}O$), which is derived from the Dryobalanops aromatica, and which apparently differs from ordinary camphor in containing the group (=CHOH) instead of (=CO). Ngai-camphor, which is obtained from Blumea balsamifera, is very closely related to borneol. Another stearoptene which has been used in medicine apart from the volatile oils, is **Menthol** ($C_{10}H_{20}O$), which is obtained from the oil of peppermint, and apparently contains a CHOH group like borneol, but is more completely hydrated. **Thujon**, an isomer of camphor occurring in the oil of wormwood or absinthe and in many other plants, has not been used in medicine, but is of great importance as the cause of epilepsy in chronic absinthe drinkers.

Local Action.—Camphor is possessed of some antiseptic action, although it is much weaker than some of the bodies of the carbolic acid group, and also than many of the volatile oils. Leucocytes cease their

movements at once when exposed to camphor solutions or vapor, and Darwin found that it acts as a stimulus to the tentacles of Drosera, an insectivorous plant, and apparently renders them more sensitive to mechanical irritation.

Camphor produces redness and a feeling of warmth when rubbed into the **Skin.** Sometimes, however, a distinct sensation of cold may be experienced, providing the rubbing is not too energetic. Menthol generally induces this feeling of cold, accompanied by more or less prickling, and afterward by heat and burning. The cold is not due to cooling of the skin, for the vessels of the part are dilated, and the thermometer indicates a higher skin temperature there than in other parts of the body. It has been ascribed to menthol being more irritant to the terminations of certain nerves which convey the sensation of cold than to those of the heat nerves and pain nerves, but this is denied by Rollett who states that menthol acts only on the terminations of the nerves of common sensation or pain. A feeling of numbness and partial anæsthesia follows its application after some time, and a 10 per cent. solution has been found to produce anæsthesia of the cornea, which, however, is preceded by pain and smarting.

When taken internally, camphor acts as an irritant and carminative on the mucous membranes like the volatile oils; it has a hot, bitter taste, and induces in small quantities a feeling of warmth and comfort in the stomach, while after large doses nausea and vomiting may be caused by gastric irritation. Some dilatation of the skin vessels follows after it is swallowed, with a sense of warmth; this may probably arise reflexly from the action in the stomach, and is comparable to the dilatation under alcohol and other slight gastric irritants. No other effects follow the use of camphor in therapeutic doses.

When large quantities are taken, they are rapidly absorbed and induce headache, a feeling of warmth, confusion, and excitement in man, with slowing of the pulse and flushing of the skin. This excitement may be shown in hilarity and delirium with hallucinations, in restlessness, or in sudden violent movements, which pass into epileptiform convulsions. These alternate with pauses of quiet and unconsciousness, which become longer until the patient sinks into complete stupor. In some cases of poisoning no excitement is observed, the patient falling into a condition of drowsiness, unconsciousness and stupor immediately. In the lower mammals, camphor induces very similar symptoms, wild excitement and epileptiform convulsions, followed by depression, stupor, collapse, and death from failure of the respiration. Not infrequently, however, the respiration ceases during a convulsion and fails to return when it passes off.

In the frog no excitement is observed except from the local irritation; the animal falls into a condition of depression, in which no spontaneous movements are made, although the reflexes seem to be little affected at first. Later, the reflexes disappear and the animal lies completely paralyzed.

Action: Central Nervous System.—In the frog camphor depresses the brain and later the spinal cord, so that the action is a descending paralysis similar to that seen under chloroform and other anæsthetics; thujon often induces violent spasms, which appear to arise from stimulation of the spinal cord and medulla oblongata.

The convulsions in mammals are certainly not due to any action on the spinal cord, but to stimulation of the higher areas of the nervous axis. The cerebral cortex is involved in the action, for the convulsions are less marked on its removal; but in the lower mammals the chief action seems to be exerted on the nervous centres situated between the cerebral peduncles and the medulla oblongata. It is not improbable that in man the cerebral action may be more marked than that on the lower areas, for on descending lower in the scale it is found that the cerebral action becomes less evident; thus in birds the removal of the cerebrum seems to have no effect on the convulsions. The loss of consciousness and the stupor observed in man and the higher animals point to a final paralysis of the cerebral cortex. Later the spinal cord and the medulla are paralyzed and respiration ceases; some observers state that the reflexes of the spinal cord are first augmented by large doses of camphor but others describe depression as the first result.

The **Terminations of the Motor Nerves** are paralyzed in the frog by large doses of camphor, but not in mammals. The **Muscles** are weakened and paralyzed when they are directly exposed to its solutions or vapor.

The **Heart** is sometimes slowed by camphor and its allies in man and animals, but is generally little affected in either strength or rate. It has been stated that the heart has less tendency to pass into fibrillation under camphor, but this is not confirmed. Similarly, camphor has been credited with dilating the coronary vessels and thus promoting the nutrition of the heart, but according to Meyer this occurs only under poisonous quantities and is therefore devoid of therapeutic interest. In the frog camphor appears to have some stimulant action on the heart muscle when directly applied to it, but in mammals its effects on the heart in therapeutically possible amounts are trifling or entirely negative.

In mammals, camphor may reduce the **blood-pressure**, though there is sometimes a transient rise at first. The slight fall in pressure appears to be due to dilatation of the peripheral vessels through direct action on their walls; the pulmonary vessels share in this dilator action. The vasomotor centre is not affected directly by small doses. When sufficient camphor is given to cause convulsions, great variations in the blood-pressure occur, a very marked rise being observed during the convulsive attacks, while in the intervals it falls to below the normal height; these variations appear to arise from a direct action on the vasomotor centre, which partakes in the general stimulation. The slight dilation of the vessels is the only change in the circulation observed after camphor, unless when quantities sufficient to cause convulsions are injected.

The **Respiration** is scarcely altered by camphor given in ordinary quantities. During the convulsions it is arrested, while in the intervals it may be accelerated from the muscular exertion during the spasms.

The normal **Temperature** is not affected by camphor, but in fever it acts as an antipyretic, like many other aromatic bodies.

Camphor is partially oxidized in the tissues, forming camphorol ($C_{10}H_{16}O_2$), which is **Excreted** in the urine in combination with glycuronic acid, $COH(CHOH)_4COOH$, and also in part in combination with a nitrogenous body, which is probably uramidoglycuronic acid. Camphorol acts like camphor, but its glycuronic acid combinations are inactive, so that the effects of camphor pass off quickly in such animals as the dog, in which these combinations are rapidly formed.

The action of borneol, menthol, bromated camphor, and camphorol is almost identical with that of camphor itself. Borneol is less irritant locally, and the convulsions are less severe than after camphor, so that animals seldom die during the convulsive stage, and may remain in a state of stupor and col-

lapse for one or two days before the respiration finally ceases. After menthol, the convulsions are even less developed than after borneol. Both of these are excreted in combination with glycuronic acid. Bromated camphor seems to resemble borneol more closely than camphor or menthol, while amido-camphor produces symptoms similar to those of camphor, but is much less powerful. Natural camphor is dextrorotary; the lævorotary isomer has been formed recently, and is found to be identical with the natural form in its action.

Preparations.

Camphora (U. S. P., B. P.) ($C_{10}H_{16}O$), Laurel camphor, a stearoptene obtained from Cinnamomum Camphora, forms white translucent, crystalline masses, which are almost insoluble in water but dissolve readily in alcohol, ether, chloroform, fixed and volatile oils. 0.2 G. (3 grs.), in emulsion or pill. As much as 1 G. has been injected subcutaneously in 10 per cent. solution in oil.

Aqua Camphoræ (U. S. P., B. P.), 10 mils (2½ fl. drs.)

Spiritus Camphoræ (U. S. P., B. P.), 1 mil (15 mins.).

Linimentum Camphoræ, camphorated oil (U. S. P., B. P.).

Tinctura Camphoræ Composita (B. P.), paregoric, contains 1 part of morphine in 2000, *i. e.*, each fluid drachm is equivalent to ¼ grain of opium. ½–1 fl. dr.

Camphor is also an ingredient in the camphorated tincture of opium, or paregoric (U. S. P.) and in soap liniment and chloroform liniment.

Menthol (U. S. P., B. P.) ($C_{10}H_{20}O$), a stearoptene obtained from the oil of peppermint, consists of colorless crystals slightly soluble in water, freely soluble in alcohol or ether.

Therapeutic Uses.—Camphor is used externally in the form of the liniment or spirit as a mild rubefacient in bruises and sprains, and also to destroy parasites. Internally the spirit is prescribed as a carminative and as an intestinal disinfectant. It is frequently given to prevent or relieve "chill," and acts here in the same way as alcohol (page 196).

There is no reason to believe that camphor in even the largest therapeutic doses has any effect after absorption except a slight dilatation of the skin vessels, and it is probable that this also may arise from its gastric effects. Its former uses in hysteria, epilepsy and other nervous disorders, as an aphrodisiac and as an anaphrodisiac were all equally irrational; if any improvement occurred, it was due to hypnotic suggestion and not to the action of the drug.

It has been used in unconsciousness and collapse arising from different causes, in the depression and weakness of acute fevers, and in the most varied forms of failure of the heart and circulation. In many of these cases, improvement in the pulse is said to have been observed; this, like the similar improvement seen after alcohol, may perhaps be explained by its action as a local stomachic irritant producing changes in the circulation reflexly; the value of camphor in heart diseases is still far from being established. Solutions of camphor in oil have been injected subcutaneously in these cases, but they cause pain and swelling at the point of injection and are valueless.

Camphor is often prescribed in expectorant mixtures, especially in combination with opium, as in paregoric.

Menthol is used almost exclusively for its effects on the sensory nerve terminations, and is applied by rubbing the crystals or sticks on the skin in case of headache and neuralgia.

Borneol and monobromated camphor are entirely superfluous. The latter was at one time used as a sedative in nervous excitement, but does not seem to have been at all beneficial and has fallen into disuse.

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3. Ether and Chloroform (Local Action).

In addition to their use as anæsthetics, chloroform and ether are sometimes prescribed for the same purposes as the volatile oils. Chloroform has a hot, sweetish taste, while ether is bitter and suffocating in the mouth; a sensation of heat and often of pain in the stomach follows when they are swallowed, and chloroform may cause gastric irritation and catarrh when given undiluted. When ether has been exposed to air and sunlight and to a varying temperature, it may contain acetaldehyde and peroxide bodies, which render it more irritant to the mucous membranes. The whole effect is similar to that produced by the volatile oils, but absorption probably takes place more rapidly. On the skin, ether evaporates too rapidly to cause much irritation, but chloroform is occasionally used as a rubefacient in the form of a liniment.

Preparations.

The pure substances may be administered by the mouth, but more frequently other preparations are prescribed.

Chloroform, 0.3 mil (5 mins.).

Æther, 1 mil (15 mins.).

Spiritus Ætheris (U. S. P., B. P.), Hoffmann's drops, 4 mils (1 fl. dr.). B. P. 20–40 mins.

Spiritus Chloroformi (U. S. P., B. P.), 2 mils (30 mins.) (5–20 m. for repeated doses, B. P.).

Aqua Chloroformi (U. S. P., B. P.).

Linimentum Chloroformi (U. S. P., B. P.).

Therapeutic Uses.—These preparations are used for the same purposes as the corresponding preparations of the volatile oils. Thus the

spirits may be prescribed as carminatives or in colic, while the liniment is used as a counter-irritant. Chloroform water is an antiseptic of considerable power, but is too volatile for surgical use.

Spirits of ether and ether itself are often given internally or subcutaneously in cases of shock or sudden collapse in the same way as brandy or whiskey, though Elfstrand states that ether injected hypodermically has no effect on the heart or blood-pressure; spirits of ether contains a much larger percentage of alcohol than ordinary whiskey. Both ether and chloroform, but more especially the latter, have been used internally for tapeworm with success. There is always some danger, however, that, besides destroying the parasite, they may cause irritation and lasting injury to the intestinal wall.

Hoffmann's drops is a favorite carminative, and is often added to other drugs to lend them an agreeable odor and taste. It is also used in dilution as a stimulant in the same indefinite way as wine and spirits, and its large percentage of alcohol entitles it to be ranked among the alcoholic preparations.

Spirit of ether is used occasionally in expectorant mixtures and is believed to increase the bronchial secretion.

Ether evaporates very rapidly and leaves a sensation of cold, and when thrown on the skin in a fine spray it produces sufficient cold to numb sensation in the part and allow of minor surgical operations (see uses of cocaine). Instead of ether still more volatile substances, such as ethyl chloride (boiling point 12.5° C.), methyl chloride (boiling point −23° C.) and liquefied carbon dioxide have been introduced. These are supplied in pressure cylinders, and are allowed to escape against the skin.

The local anæsthesia produced bears no relation to their action when inhaled, but is due simply to the cold produced by their evaporation. The vessels of the part contract, and the absence of blood and hardness of the tissues facilitate some operations, but the subsequent reaction is liable to produce considerable soakage of blood from the wound. The cold elicited ought not to be great enough to actually freeze the tissues, otherwise the healing may be slow. The intense cold is often quite as painful as the operation itself would be without any anæsthetic.

4. **Malodorous Volatile Oils.**

Some of the volatile oils differ from the others in possessing an odor which is disagreeable and nauseating to most people, although not to all. The best known of these are the *Oils of Asafœtida* and *Valerian*. The former occurs along with resins and gums exuding from some species of Ferula, and contains several organic sulphur compounds, to which it owes its odor. Oil of Valerian, from Valeriana officinalis, is almost without odor when freshly distilled, but when kept for some time and exposed to the air, it assumes a somewhat unpleasant penetrating odor. It contains two terpenes, borneo-camphor, and numerous esters of formic, acetic and valerianic acid. While both of these oils

are generally regarded as possessing very unpleasant odors, asafœtida is used in India as a condiment, and valerian was formerly used in England as a perfume. Another drug of the same kind formerly in use is *Sumbul*, the root of Ferula Sumbul.

Asafœtida and valerian are used in hysterial affections, and the benefits accruing from their administration have generally been attributed to the mental impression produced by their unpleasant odor and taste, and not to any action they produce after absorption. Macht[1] observed a sedative action in rats after the inhalation of traces of asafœtida and valerian preparations.

The ordinary valerianic salts have no further effects than other salts of the acetic acid series, so that it is quite irrational to use such bodies as valerianate of quinine for their action in hysteria.

Asafœtida is also used like the ordinary volatile oils as a carminative and as an expectorant, and the emulsion is given by the mouth or in an enema to relieve abdominal distention.

Preparations.

Asafœtida (U. S. P.), a mixture of volatile oil, gum, and resin from Ferula fœtida and other species. 0.25 G. (4 grs.)

Emulsum Asafœtidæ, 15 mils (4 fl. drs.).

Tinctura Asafœtidæ, 1 mil (15 mins.).

Asafetida (B P.), a gum-resin obtained from the root of Ferula fœtida and probably other species. 0.5 G., 5–15 grs.

Tinctura Asafœtidæ, 2 mils, ½–1 fl. dr.

Pilula Aloes et Asafœtidæ, 0.5 G., 4–8 grs.

Valeriana (U. S. P.), **Valerianæ Rhizoma** (B. P.), valerian, the rhizome and roots of Valeriana officinalis. Dose, 2 G. (30 grs.)

Tinctura Valerianæ (U. S. P.), 4 mils (1 fl. dr.).

Tinctura Valerianæ Ammoniata (U. S. P., B. P.), 2 mils (30 mins.).

VII. SKIN IRRITANTS AND COUNTER-IRRITATION.

The practice of applying irritants to the skin in internal diseases is one of great antiquity. The theories on which this therapeutic method is based have changed with the advance of medical knowledge, until, no explanation satisfactory to modern scepticism being forthcoming, the use of these remedies has fallen into a certain disrepute in the last few years. The old theory of revulsion or derivation was at first based on the belief that disease was a malignant entity or humor, which might be drawn from the deeper organs to the surface by means of irritation of the skin. Later, it was supposed that the congestion of the diseased organs might be relieved by the withdrawal of fluid to the skin, and this belief has been held in more or less modified forms in quite modern times. In addition, it was recognized very early that irritation of the skin relieved pain in many instances. The means by which the skin irritation was attained were extremely numerous and varied; large numbers of drugs have been used, and in addition mechan-

[1] Jour. Pharm. and Exp. Ther., xviii, p. 361.

ical devices of all kinds were employed, such as burning, electrical currents, or the introduction of setons. In many of these the idea of irritation was combined with that of leaving a way of escape for humors. This latter is only of historical interest, but the practice of relieving internal organs by external irritation or *counter-irritation* persists still, and perhaps merits more attention than it receives at the hands of many physicians.

The effects of an irritant applied to the skin are local and remote. The first symptoms of irritation are congestion and redness of the part, and many drugs which produce only this degree of irritation in ordinary circumstances, are known as *Rubefacients*. Stronger irritants cause blistering, and are called *Vesicants*, while some drugs which cause irritation and small discrete suppurations, receive the name of *Pustulants*.

Local Symptoms.—The application of an irritant to the skin causes a feeling of warmth, and often of itching, which may later become intensified into actual pain. The skin becomes red, congested, warm, and at first is more sensitive to touch and painful stimuli, though the sensitiveness is afterward lessened. This condition persists for a longer or shorter time according to the nature of the irritant, and then passes off slowly. Very often desquamation follows, if the rubefacient has acted for some length of time. Stronger irritation is followed at first by the same results, but soon small globules of fluid appear below the epidermis, and these coalesce so as to form a large accumulation of fluid, which raises the epidermis completely off the true skin, forming a blister. If the irritant be removed, the fluid of the blister undergoes a slow absorption, so that in the course of a few days the epidermis forms an empty sack, which, however, is not obliterated by the adhesion of the walls. If the blister be opened, the sensitive dermis is exposed, and the secretion of fluid continues for some time, until a new epidermis has been formed.

The distinct and separate points of inflammation caused by the pustulants are due to their affecting the orifices of the skin glands and not intervening tissue. This has been ascribed in some instances to the drug being rendered irritant at these points by the presence of acids formed by the decomposition of the sebum and perspiration; a simpler explanation is that the pustulants cannot pass through the horny epidermis, but act as irritants wherever they come in contact with living tissue, that is, at the orifices of the glands. They cause the same sensation of warmth and prickling of the skin as the other irritants, but even in the earlier stages of their action small, dark-red, raised points are observed, exactly as in some of the exanthemata, and these afterwards form small abscesses. If the application be persisted in, these discrete abscesses may burst through the intervening tissues and become confluent, and large abscesses have thus been formed in the skin. When the irritant is removed before the formation of pus, the inflammation of the ducts slowly subsides and the epidermis peels off as after the milder irritants. Pustulants are seldom employed at the

present time; croton oil applied vigorously may induce pustulation, and tartar emetic was formerly largely used for this purpose.

The local effects of the rubefacients and vesicants are identical with those of acute inflammation. The pain and discomfort are due to the action on the nerve terminations, while the redness and swelling betray the local dilatation of the vessels. This latter appears to be due to a reflex from the sensory terminations to the vasodilator nerve ends on the vessels; the central nervous system is not involved in this reflex, for it occurs after division of the nerves of the part, but not after the peripheral fibres have degenerated; it is thus of the nature of an axon reflex (Bruce). The dilatation of the vessels and the slowing of the blood current in them lead to the transudation of fluid and leucocytes into the tissues, especially at the points where the irritation is greatest, and the accumulation eventually pushes off the horny epidermal layer from the living layers and forms a blister. The fluid in the blister has been shown to contain some of the irritant, which diffuses into it through the epidermis. The œdema and swelling is not confined to the skin, but extends into the subcutaneous tissue and the more superficial layers of muscle.

If the irritation be continued long enough, suppuration may commence in the blister and lead to deep erosion of the tissues.

Remote Action.—Local irritation cannot exist without causing certain general changes which affect the whole organism, and which arise from the reflex stimulation of various centres in the medulla oblongata. Attempts to base the explanation of counter-irritation on these general effects have all failed, however, and many of them are elicited only by widespread irritation or by more intense localized irritation than is induced by ordinary therapeutic methods.

The centres involved are those regulating the heart, the tone of the vessels, and the respiration. Moderate irritation of the skin causes an acceleration of the heart-rhythm, while more powerful irritation slows the heart through the inhibitory centre. The blood-pressure measured in the arteries is considerably increased by ordinary irritation of the skin, but if it be very severe or widespread, the slowness of the pulse may cause a fall of tension. This increase in the blood-pressure is due to the reflex stimulation of the vasomotor centre, which causes a constriction of the arterioles of the abdominal organs chiefly, while the vessels of the limbs and probably those of the skin are not contracted. The result is that more blood is supplied to the muscles and skin and less to the internal organs than normally.

The effects of skin irritation on the respiration are less uniform. In the rabbit the breathing is sometimes accelerated, sometimes slowed by mild stimulation, while stronger stimuli seem to slow it always. The effect of the application of skin irritants on the respiration in man has not been observed accurately, but that sudden stimulation of the skin causes gasping and irregularity of the respiration, may be observed whenever cold water comes in contact with the more sensitive parts of the body.

Some change in the temperature of the body has been observed when the skin is irritated, but in man this is said to amount to less than 0.1° C. as a general rule. The internal heat tends to fall, while that of the skin rises, from the change in the distribution of the blood which has been described above.

The metabolism has been found to be altered by the application of irritants

to the skin, and, although in the experiments on which this statement is based, the surface exposed to the irritant was larger than that affected in therapeutics, it seems probable that some change is produced by the ordinary agents also. Zuntz and Röhrig found that bathing animals in strong salt solution increased the oxygen absorbed and the carbonic acid excreted much more than bathing in ordinary water, and Paalzow obtained the same result from the application of mustard plaster. The nitrogen of the urine is also said to be increased. This increase in the oxidation of the tissues is of the same nature as that produced by cold, and is due to an augmentation of the muscular activity, which, however, is too slight to cause any perceptible movement.

Irritation of the skin induces leucocytosis in the same way as irritation of the alimentary canal. This is especially evident after the application of a vesicant such as cantharides plaster, while rubefaction seems to have less effect.

Lastly, in considering the effects of skin irritation on the general vitality, it may be mentioned that a sudden application may awake the consciousness, as is seen in the effects of dashing cold water on the chest, or of striking the hands in narcotic poisoning. Another example is seen in the improved mental condition so often observed in fever patients treated with cold baths. This improvement is due to the local action on the skin, and not, as is often said, to the fall in temperature, for the latter is often insignificant.

All of these effects are produced by irritation at any point of the surface, and are quite insufficient to explain the practical use of counter-irritants to affect a particular organ. For example, in gastric disorders a counter-irritant is often applied just over the ensiform cartilage, while in facial neuralgia a blister behind the ear often gives relief. If the beneficial results were due to the general alteration of the circulation, respiration, or temperature, there would be no reason to vary the point of application, for the effect would not vary.

It has been shown by several observers (Zuelzer, Lazarus-Barlow) that when an irritant is applied to the skin, the muscles beneath are congested and rich in lymph, and Erlanger states that solutions are absorbed more quickly from the pleural cavity when mustard is applied to the skin of the chest and attributes this to an acceleration of the lymph stream. But these observations apply only when the organs to be affected are not only contiguous, but also continuous with those directly affected, and offer no explanation of the effects of irritation of the skin upon the stomach or lungs.

Much light has been thrown on the subject by the observations of Mackenzie and Head, who found that visceral disease is often accompanied by tenderness of the skin and underlying muscles, and that the pain arising in these cases is referred to this area of skin and not to the organ involved. Thus in painful diseases of the stomach, tenderness is often found in the skin and muscles of the epigastrium, while in œsophageal stricture, pain may be referred to a point near the angle of the scapula and to another in the neighborhood of the apex beat. Similarly in heart disease, pain is often felt in the left chest-wall and shoulder extending down the left arm. These points are, of course, only connected with the diseased organ by means of nerve-fibres, and it thus appears that impulses from such an organ arouse a condition of heightened sensibility in the region of the cord

on which they impinge; this affects all the synapses in the neighborhood (Fig. 1), so that impulses from very different structures may be altered by the affection of one. The sensation of pain aroused by this exaggerated sensibility is of course referred to the periphery, not to the focus in the cord, and this gives the impression of tenderness in the skin and muscles. It therefore seems probable enough that an affection of these superficial areas may affect the corresponding internal organ more than the rest of the body, and this is exactly what is required to explain the benefits derived from the use of counter-irritants. It is especially noticeable that several of the skin areas affected by internal disease are precisely those points at which experience has

FIG. 1

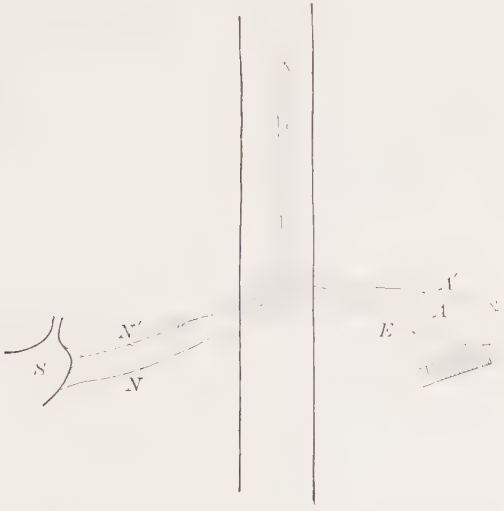


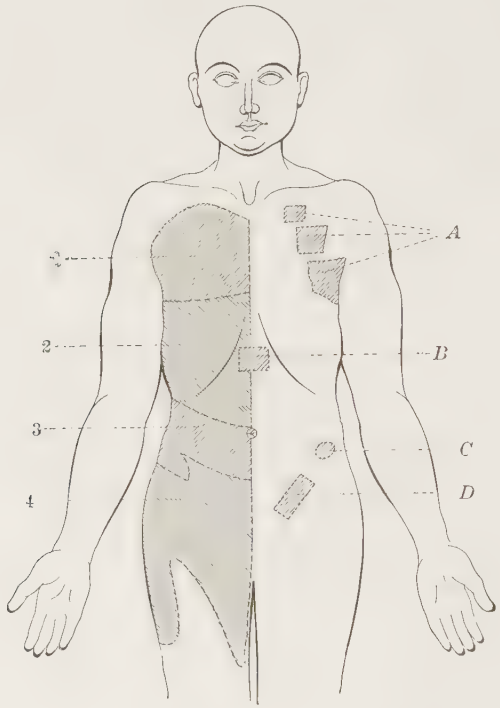
Diagram to illustrate the effects of visceral disease on sensation (after Mackenzie) *S*, diseased viscus, with afferent nerve fibre *N* and efferent fibre *N'* issuing from the same area of the spinal cord. The impulses from the diseased area induce a condition of heightened sensibility in the shaded area. *E*, a motor nerve fibre to muscle, which carries more impulses than usual from the area in the cord and thus leads to a tonic contraction of the muscle. *A*, the afferent nerve from the muscle and *A'* from the skin entering the cord in the sensitive area and thus giving rise to the sense of pain and tenderness, which is referred to the peripheral distribution in the skin and muscle.

shown irritation to be most beneficial (Fig. 2). Thus the application of a blister over the epigastrium has long been recognized as a means of relieving gastric disorders. Similarly the old treatment of iritis by means of a blister on the temple may be justified by the fact that Head found areas of tenderness on the temple accompanying this disease.

The exact nature of the effects of counter-irritation on the internal organs has not been ascertained, but it would seem most probable that an alteration in the calibre of the vessels is induced. These alterations may be accompanied by changes in the activity of the organs; for example, there seems good reason to believe that in many cases irritants

applied to the abdomen produce evacuation of the bowels. The most obvious effect of counter-irritation very often is the relief of pain, and this seems explicable in the light of the observations of Mackenzie and Head. For if the pain in visceral disease is due to the disorder of the synapses in the spinal cord at the level at which the fibres from the viscus and from the superficial tissues meet, it is possible that new impulses reaching this area from the skin may alter its condition

Fig. 2



The right side is divided into segments which correspond to some of the skin areas in which Head found tenderness in internal diseases. 1. Area of tenderness in disease of the lungs. 2. In diseases of the stomach. 3. In ovarian disease. 4. In disease of the Fallopian tubes and other appendages. On the left side are represented the points of application of counter-irritants in disease of the lungs (*A*), of the stomach (*B*), of the ovary (*C*), and the uterine appendages (*D*).

or may occupy a common path to the brain to the exclusion of impulses arising from the seat of disease. Or, if the pain arises from cramp in a superficial muscle innervated from the same level of the cord as the diseased viscus, an irritant applied over the muscle may increase its circulation and warmth and thus relieve the cramp and the pain.

Besides these physiological effects of counter-irritation, it must not be forgotten that a great impression is produced on the patients, and that some of the benefit may be due to hypnotic suggestion.

Therapeutic Uses. — Local irritants are applied occasionally to produce an alteration in the nutrition and blood supply of the skin itself and of the subcutaneous tissues. Thus in some chronic inflammatory conditions, with effusions into, or indurations of the subcutaneous tissues, the improvement of the circulation produced by slight irritation may be of benefit. An example of this is the treatment of ulcers of old standing with irritants. Another case in which a slight inflammatory attack causes very obvious improvement, is in corneal opacity, which may be removed entirely in some cases by the acute inflammatory reaction produced by such irritants as abrin. Probably a similar effect is produced on subcutaneous effusions, as in bruises. It has been found experimentally that when abscesses in the subcutaneous tissues are treated with mild irritation of the skin over them, they improve more rapidly than controls left without treatment; the increased blood supply leads to a larger supply of leucocytes and protective substances around the inflammation than would otherwise be present. Similarly, the absorption of pigments injected into the rabbit's ear is much accelerated by the application of irritants to the skin over the part, which suggests that toxins are removed more rapidly under similar treatment (Wachsberg). Sollmann induced a series of nodules in the skin of his forearm by intracutaneous injections and found that their disappearance was hastened by the application of iodine over them. For these purposes only the milder irritants are required; in fact, vesication may do more harm than good.

Mild irritation alters the sensitiveness of the sensory organs of the skin, and heat is often applied to alleviate pain and discomfort in the skin itself. In other instances pain is increased by heat, and, in fact, it is sometimes applied in the treatment of local anæsthesia, with the object of rendering the surface more sensitive. In many forms of skin disease, mild irritants are found to be of benefit; this is sometimes attributed to their antiseptic action, but the slight irritation is undoubtedly of some importance.

Counter-irritants are used in a large number of diseases, often without any definite idea of what precise effects they will elicit, but merely because they have been found to give relief in similar conditions. As a general rule they are placed over the affected organ, and this corresponds fairly in most cases of disease of the trunk with Head's area of skin tenderness. In the head, however, the segmental arrangement has been rendered very irregular by the compression in development, and counter-irritants are often found to be most effective when placed at some distance from the seat of pain, *e. g.*, behind the ear in some forms of facial neuralgia. They are used in acute inflammation of the lungs and pleura, in gastric disorders accompanied by much pain, in colic and in neuralgia and neuritis. Their action is very uncertain, but their application is often followed by great relief, more especially of pain. They are also used occasionally in shock or collapse, not for their effect on any individual organ, but to elicit the reflex alterations in the circulation which have been described already. A

blister is often recommended in internal hæmorrhage, and may very possibly lessen the bleeding by altering the distribution of the blood in the organs, although it is difficult to estimate how far the improvement is due to the remedy and how far it is spontaneous. In order to produce any marked effect on internal organs, the more powerful irritants must be used, such as mustard or cantharides. It is not necessary, however, to produce actual vesication in the great majority of cases. Formerly blisters were opened and fresh irritants applied on the raw surface in order to prolong the effects, but this treatment was extremely painful, besides being liable to set up suppuration and ulceration, and it is very questionable whether any equivalent benefit followed.

Counter-irritation must be applied only with the greatest caution in weak, badly nourished, or very old persons, as it may cause sloughing. In diabetes, the tendency to gangrene contra-indicates blistering, and in very young children only mild irritants are used.

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An enormous number of drugs produce irritation of the skin, and it would be idle to attempt to enumerate them here. In many instances, however, the irritant action is insignificant in comparison with the other effects produced, and these will, therefore, be discussed elsewhere; among these are found some of the alkaloids, the acids and alkalies, and many other inorganic preparations. Irritation of the skin may also be produced by heat and cold, and in fact burning in various forms was formerly used as a means of counter-irritation. Heat is still employed to cause irritation of the skin and subcutaneous tissues, and to promote their circulation. Thus, poultices, and hot water compresses are beneficial in many local inflammations, though the same effects may generally be obtained by the use of the milder irritants. A variety of apparatus has been devised for the application of air heated to 250° F., or even higher to rheumatic joints, and relief often follows from this, as from the older methods of poultices and compresses. Another method by which hyperæmia of a whole limb may be attained has been introduced by Bier, who advises the application above the seat of disease of an elastic bandage which is tight enough

to retard slightly the venous flow, but leaves the circulation of the limb otherwise intact; satisfactory results have been recorded from this treatment in many conditions, and these are generally ascribed to the accumulation of leucocytes and alexines in the tissues. Somewhat similar results may be obtained in the trunk by dry cupping, in which the blood is drawn to the diseased superficial tissue by applying a glass tightly to the skin and exhausting the air in its interior. Another method by which chronic inflammatory conditions have been treated with the view of inducing an acute reaction is the application of solid carbonic dioxide; this has been employed chiefly in open wounds and in disease of mucous membranes.

Apart from those drugs in which the irritation of the skin is merely an incident in a wider general action, there are a number of preparations which are used almost exclusively for this purpose. They may be divided into three classes: the volatile irritants, such as turpentine oil; the mustard series, some of which are also volatile; and those which are either non-volatile or only boil at high temperatures, such as cantharidin.

1. The Turpentine Oil Group.

Under the volatile irritants may be included a large number of the ethereal oils and many members of the methane and of the aromatic series; but among the ethereal oils those which possess a low boiling point, that is, those which contain a large proportion of terpene, with comparatively little oxygen, are found to possess a more penetrating action than the others. At the same time, the taste and odor of these oils is often less pleasant than that of the others, so that they are less used as flavors and carminatives. The oils derived from the Coniferæ have, for this reason, been more largely used than the others for their effect on the skin, although several other volatile preparations are recognized by the pharmacopœia for this purpose. The action of these oils is similar in other respects to that of the general group (see p. 61), so that it need not be discussed here.

Preparations.

Oleum Terebinthinæ Rectificatum (U. S. P., B. P.), is formed from ordinary oil of turpentine by redistillation and consists of a mixture of terpenes ($C_{10}H_{16}$). Dose, 0.3 mil (5 mins.); as an anthelmintic, 8–15 mils (2–4 fl. drs.).

Emulsum Olei Terebinthinæ (U. S. P.), 2 mils (½ fl. dr.).

Linimentum Terebinthinæ (U. S. P., B. P.).

Linimentum Terebinthinæ Aceticum (B. P.), is formed by mixing turpentine, glacial acetic acid, and camphor liniment.

In addition to these preparations the following may be mentioned here as possessing similar action and uses.

Linimentum Chloroformi (U. S. P., B. P.).

Linimentum Camphoræ (U. S. P., B. P.).

Linimentum Camphoræ Ammoniatum (B. P.).

Linimentum Saponis (U. S. P., B. P.), very slightly irritant.

Arnica and its preparations enjoy a popular reputation as skin applications but do not appear to have any action which entitles them to consideration.

Therapeutic Uses.—Turpentine oil is used externally as a rubefacient, and differs from mustard and cantharidin in its greater penetrating power. It is not so irritant, however; it blisters only after long application, and the vesication produced is very painful and heals slowly, from the vapor penetrating into the deeper tissues. It is, therefore, employed to produce rubefaction only, and ought to be removed when this is attained. For this purpose any of the liniments of the group may be employed, or a more intense action may be got from the "turpentine stupe," which is made by dipping flannel in hot water, wringing it dry, and then dropping warm turpentine oil on it.[1] Turpentine preparations are used especially in rheumatic affections of the joints or muscles, and in sciatica. Turpentine oil is a fairly strong antiseptic, and is less irritant than many of the more powerful ones. It is often inhaled in lung diseases such as tuberculosis or gangrene, and has the effect of lessening the odor in the latter; the oil may be simply allowed to evaporate, but is much more efficient when sprayed into the air. Many of the resorts for phthisical patients are stated to be rendered especially suitable for this disease by the neighborhood of coniferous forests, which are supposed to dissipate the oils into the atmosphere; but this is probably only an insignificant factor in the treatment. Turpentine oil is occasionally added to baths in order to cause a slight general irritation of the skin, which may be of benefit in some skin diseases and also in general debility under certain conditions; and pine-needle baths have some reputation in Germany for the same reason, the water being supposed to extract the oil.

Internally, turpentine oil is occasionally employed as a vermifuge, but is inferior to other preparations used for this purpose. A few drops are often added to purgative enemata to increase their efficiency. It has been given by the mouth in order to lessen flatulence and to disinfect the intestine in various diseases, among others, typhoid fever, although its value here is disputed. Preparations of turpentine oil and juniper are reliable and fairly powerful diuretics, but must not be prescribed in irritation of the kidney. The turpentine preparations have a certain reputation as expectorants; they are also given internally as pulmonary disinfectants and in neuralgia and internal hemorrhage, and are probably entirely valueless for these purposes. Old oil of turpentine was formerly advocated in phosphorus poisoning, but this treatment has proved to be erroneous.

Some remedies which produce irritation of the skin of approximately the same degree as turpentine oil, but which are discussed elsewhere are camphor, chloroform, dilute acetic acid, ammonia, alkalies, alcohol, iodine and some of the heavy metal preparations.

2. Mustard.

Mustard occurs in two forms in the pharmacopœias, Black Mustard, Sinapis nigra, and White Mustard, Sinapis alba. Black Mustard

[1] Alcohol has recently been applied in a similar way in phlegmon and other forms of inflammation. Gauze is soaked in alcohol (60–96 per cent.), wrung out, wound round the affected part and covered with cotton and oil-cloth.

contains a glucoside, *Potassium Myronate* or *Sinigrin*, and a ferment, *Myrosin*, which decomposes it in the presence of water into dextrose, potassium bisulphate and allyl-isosulphocyanate, or volatile oil of mustard.

Sinigrin. Volatile oil.

$$C_{10}H_{18}KNS_2O_{10} = CSNC_3H_5 + C_6H_{12}O_6 + KHSO_4$$

Volatile oil of mustard is formed in various other Cruciferæ when they are mixed with water. Thus horseradish root (Armoracia, B. P.) contains it, while the allied species Cochlearia officinalis apparently contains the corresponding isobutyl compound.

White mustard contains another glucoside, *Sinalbin*, which is also decomposed by the *Myrosin* in the presence of water. The products are entirely different, however, dextrose, sulphate of sinapine (an alkaloid), and an oil of mustard containing an aromatic nucleus being formed.

Sinalbin. Oil of mustard. Sinapine sulphate.

$$C_{30}H_{44}N_2S_2O_{16} = C_6H_4(OH)CH_2NCS + C_{16}H_{23}NO_5H_2SO_4 + C_6H_{12}O_6$$

The oil of white mustard differs from that of the black in being less irritant, and in being destroyed by heat.

Action.—Either of these oils is intensely irritant when applied to the skin, and if left long enough produces blistering, which is more painful than that caused by cantharides, and is said to heal less readily. This is probably due to the oils penetrating more deeply into the tissues, and thus setting up more extensive inflammation. Mustard is accordingly used only to induce rubefaction, and ought to be removed before actual vesication occurs. When the crude drug is moistened and applied to the skin, the oil is formed only slowly, so that the longer it remains applied, the more intense is the action. The glucosides in themselves have little or no action, and the products of their decomposition are harmless, with the exception of the oils.

Preparations.

Sinapis Alba (U. S. P.), the dried ripe seeds of Sinapis alba.

Sinapis Nigra (U. S. P.), the dried ripe seeds of Brassica nigra.

Emplastrum Sinapis (U. S. P.), black mustard powder rendered adhesive by India-rubber, applied to sheets of paper and dried.

Oleum Sinapis Volatile (U. S. P., B. P.), derived from black mustard.

Linimentum Sinapis (B. P.), formed from volatile oil of mustard, camphor, and castor oil.

Uses.—Mustard is largely used as a condiment and to promote appetite, but is never prescribed for this purpose. In large quantities it causes violent irritation of the stomach and bowel, with vomiting, purging, acute pain and tenderness in the abdomen, and collapse. Mustard and warm water is a convenient emetic in emergencies, as in cases of poisoning.

The plaster or leaf (charta) is the form in which it is generally used in therapeutics. It contains the glucoside, which is slowly decom-

posed by the ferment when the plaster is dipped in warm water for a few minutes before application. Another popular application is the mustard poultice, in which powdered mustard is sprinkled on an ordinary poultice. Mustard is also added to baths occasionally when slight irritation and consequent congestion is desired over a large surface. For this purpose 2–4 teaspoonfuls of the dry powder are added for each gallon of water. In preparations of mustard it is important to avoid a temperature of over 60° C. (140° F.), as the ferment is destroyed above this. The plaster is left on the skin only for 15 to 30 minutes, when it is used as a rubefacient.

3. Cantharidin Series.

Another series of local irritants comprises non-volatile substances, of which cantharidin ($C_{10}H_{12}O_4$) is the best known. It is an anhydride and when acted on by bases forms cantharidates, which resemble it in action. It is found in Spanish fly (Cantharis vesicatoria, or Lytta vesicatoria) and in several allied species of Coleoptera (beetles).

Action.—Applied to the *skin*, cantharidin produces redness, smarting and pain, followed very soon by small vesicles, which later coalesce into one large blister. This is much less painful than the vesication produced by mustard, because less of the irritant penetrates into the deeper tissues than in the case of the volatile mustard oil. If the blister be broken, however, and the unprotected dermis be allowed to come in contact with the irritant, violent inflammation with much pain, suppuration and even sloughing may follow.

When large quantities of cantharidin are given *internally*, the same irritant action takes place along the alimentary tract. If taken in solution, blisters arise in the mouth and throat, and the pain and swelling in the œsophagus may be so acute as to prevent swallowing. The irritation of the stomach produces vomiting, followed by purging with excruciating pain in the abdomen, and all the symptoms of shock and collapse.

Cantharidin is absorbed from the alimentary canal, and also to a less extent from the skin, but has no important action on the internal organs, with the exception of those by which it is eliminated. Vomiting occurs on subcutaneous injection from some of the poison being excreted into the alimentary tract. Comparatively small quantities irritate the bladder, and cause a constant desire to micturate, with pain in doing so. In somewhat larger amount it sets up an acute nephritis with albuminuria, pain in the kidney region, and sometimes blood in the urine. The inflammation of the bladder and urethra produces intense pain and often priapism; in women abortion is said to occur occasionally, and in both sexes the irritation may lead to increased sexual desire.

The irritation of the kidneys by small doses increases their secretion, and cantharides was therefore considered a diuretic formerly. The tendency to produce nephritis renders it a dangerous internal remedy,

however, and its diuretic power is quite insignificant in comparison with that of caffeine.

Animals vary very considerably in the degree in which they react to cantharidin, the most noted example being the hedgehog, which is capable of surviving a dose of the poison sufficient to poison an adult man. Fowls and rabbits also possess a high degree of congenital tolerance for this poison, although none of these is absolutely insusceptible to it.

Preparations.

U. S. P.—**Cantharis**, Spanish Fly, the dried beetle, Cantharis vesicatoria.
Ceratum Cantharidis.
Emplastrum Cantharidis.
Collodium Cantharidatum.
Tinctura Cantharidis, 0.1 mil (1½ mins.)
B. P.—**Cantharidinum**, $C_{10}H_{12}O_4$, obtained from various species of Cantharis or of Mylabris.
Emplastrum Cantharidini, containing 0.2 per cent.
Emplastrum Calefaciens, warming plaster, 0.02 per cent.
Unguentum Cantharidini, 0.033 per cent.
Liquor Epispasticus, blistering liquid, 0.04 per cent.
Tinctura Cantharidini, 0.01 per cent. 2–5 mins.

Therapeutic Uses.—This drug is at present used almost exclusively as a skin irritant, and more particularly as a vesicant. The plaster is the form generally used. It is to be noted that in order to produce actual blistering, the plaster has to remain in contact with the skin some eight to ten hours, but an equal effect may be achieved by replacing the plaster by a hot poultice after four to six hours, when the skin irritation has reached the stage of redness. The ointment is said to induce blistering sooner than the plaster. Cantharides is also used to cause rubefaction and commencing vesication (flying blister); this may be done by the use of the plaster, or by means of the warming plaster, B. P. Blistering collodion or blistering liquid, is used rarely in unmanageable cases in which there is a risk of the plaster being removed by the patient.

Cantharidin is liable to be absorbed from the skin, and its application is therefore avoided where there is any tendency to renal inflammation.

Cantharides has been used not infrequently as an aphrodisiac, and several cases of poisoning have occurred from its administration for this purpose. In cattle it is largely employed to this end in some countries, and in man it has undoubtedly similar effects in some cases[1] through the irritation of the bladder and urethra, but its use for this purpose is always liable to produce nephritis. As an emmenagogue, cantharides has a certain popular reputation, which, however, has been shown to be unmerited, any influence which it may possess on the menstrual flow being quite insignificant, and probably due only to the irritation of the bladder and urethra.

[1] The "hot Hispanian fly" is mentioned as ingredient of Calypso's love philtre. (Cumberland).

Cantharides has been advised internally in some forms of renal and vesical disease, but it is an exceedingly dangerous remedy in these conditions. It is sometimes a constituent of hair washes, its irritant action on the skin being credited with causing a more rapid growth of the hair.

In cases of **Poisoning** with cantharides, the stomach ought to be emptied as rapidly as possible by the stomach tube, provided the œsophagus allows of its passage. Demulcents and albuminous substances are of use in slowing the absorption, but all oily or fatty bodies must be avoided, as they tend to dissolve the cantharidin and thus promote its absorption. Opium may be given for the pain, and if collapse sets in, the ordinary measures must be taken to combat it. Ellinger states that the action on the kidney in rabbits is more severe when the urine is acid than when it is alkaline, and this suggests the treatment of the renal symptoms with alkalies.

Poison Ivy and Poison Oak.—The commonest form of poisoning in the United States is the skin eruption produced by the leaves of poison ivy and poison oak (Rhus toxicodendron and venenata), which Pfaff showed to be due to the presence of a neutral body, *Toxicodendrol.* The effects of poison ivy can arise only from touching the plant, the poisonous principle not being volatile. Very minute quantities of toxicodendrol are sufficient to produce skin eruptions, however, $\frac{1}{1000}$ mg. causing distinct symptoms in susceptible persons. The popular belief that skin affections can be induced by approaching the plant, without actually touching it, is probably accounted for by the facts that the eruption may be very late in making its appearance, and that poison ivy is very frequently mistaken for harmless climbing plants. The statement that the poison ivy does not affect some individuals is also probably erroneous, though persons of delicate skin are undoubtedly more susceptible. Immunity is not acquired for the poison by repeated attacks of dermatitis.

In the dermatitis from poison ivy, Pfaff recommends the skin to be washed and scrubbed with soap and water, or with alcohol, or a solution of lead acetate in alcohol. Ointments and oily liniments are to be avoided, as they dissolve the toxicodendrol and tend to spread it over the skin and thus produce further inflammation. For the same reason, the alcohol used to wash the part must be removed entirely, as the poisonous principle is soluble in it, while insoluble in water. Potassium permanganate solution is said to be an efficacious application.

Eruptions similar to that from poison ivy arise from contact with a number of other plants of which the best known is the *Primula obconica;* this plant secrets some unknown substance which is intensely irritant to the skin of many people, and has frequently given rise to severe inflammation in gardeners and others. Cash found an alkaloid obtained from East India Satinwood (*Chloroxylon*) equally irritant when applied to the skin; the dermatitis from these bodies often appears only two to three weeks after contact with them, and even after apparently complete recovery the skin remains especially sensitive to a reapplication of the poison.

Dichlorethylsulphide, or Thiodiglycolchloride $(ClH_2ClH_2)_2S$, the notorious "Mustard Gas" of the Great War, is an artificial substance which rivals or perhaps excels toxicodendrol in its irritant and destructive action on the skin, and which, being volatile, penetrates to the lungs and proves fatal through pulmonary irritation when inhaled in even minute quantities.

A number of the Ranunculaceæ are irritant to the skin like cantharides, but the active constituent has not been definitely determined. *Mezereum*, which was formerly official, is similarly irritant, apparently from the presence of an irritant oil (Springenfeldt). *Cardol*, found in the fruits of Anacardium occidentale and in Semecarpus anacardium, is a very powerful irritant, and has been used to a limited extent as a vesicant. Cardol is probably a mixture of a number of substances, but it is unknown to which of these it owes its activity. *Euphorbin* is said by Buchheim to be the irritant principle in the Euphorbia resin (Euphorbia resinifera, etc.), and to resemble cantharidin in its anhydride form, but the salts and the euphorbic acid which is formed from them by acids are inactive. A very poisonous member of the Euphorbiaceæ is the Manicheel tree, growing in the West Indies, and it apparently belongs to this series.

Capsicum (p. 58) contains one or more non-volatile irritant substances and is used occasionally as a skin irritant. Pepper is also used as a rubefacient in domestic medicine.

Chaulmoogra Oil, obtained from Taraktogenos Kurzii, is apparently similar in character to the members of this group, although it is less irritant. It is used externally as an application to bruises, and both externally and internally in leprosy.

Many other plants possess irritant, poisonous properties, which would apparently entitle them to a place in this series, but so little is known of their active principles and of their effects, that they may be omitted for the present.

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VIII. VEGETABLE PURGATIVES.

Purgatives are drugs which are employed in medicine to evacuate the bowel of its contents. Many drugs produce evacuation in the course of their action, but have other effects of importance and are not included in this class; for example the skin irritants if taken by the mouth may cause diarrhœa, but this is accompanied by irritation of the mouth, throat and stomach, and these preclude their use as purgatives. The ideal purgative is devoid of any effects whatsoever, save in the intestine; it passes through the stomach without materially deranging its function,

and is not absorbed, or at any rate has no significant action after absorption. The vegetable purgatives act through their irritant properties, which in some instances are elicited only by the action of the secretion of the intestines and of the neighboring glands. Thus some of the purgatives pass through the stomach in the form of bland, non-irritant compounds (castor oil), which are broken up by the digestive processes in the intestine, while others perhaps owe their activity in the intestine to their solution or suspension in the juices.

Many classifications of the purgatives have been based on their effects, and some of the terms are still retained, such as *aperient, eccoprotic, laxative, purgative, cholagogue, hydragogue, cathartic, or drastic.* But the effect of the purgatives is determined largely by the dose and by the condition of the intestine, so that a small dose may act as an aperient, laxative or eccoprotic, while a larger quantity of the same drug, or even the same dose in a more susceptible individual, may act as a drastic or hydragogue cathartic. They are therefore classified in three groups: (1) the mild aperients, castor oil group; (2) the purgatives of the anthracene series; (3) the jalap and colocynth group.

Symptoms.—In moderate doses the purgatives simply hasten the normal movements of the intestines, and the stool is of the ordinary appearance and consistency (laxative, aperient, or eccoprotic action). In larger quantities they cause a more profuse evacuation than normally, and the stools, which are repeated at short intervals, are of a looser, more fluid consistency. Their action is accompanied by considerable pain and colic, and the hurried movements of the intestine are shown by the characteristic gurgling sounds. Large quantities of the more powerful purgatives may cause all the symptoms of acute enteritis, the stools at first contain the ordinary fæcal substances accompanied by more fluid than usual, but later consist largely of blood-stained mucous fluid with little or no resemblance to ordinary fæces. This violent purgation, which is not induced in therapeutics, is accompanied by pain and tenderness in the abdomen, and may induce shock, collapse, and eventually death.

Action.—The peristaltic movements of the intestine which move the contents along the canal, arise from a complicated local reflex, which is aroused by the pressure of the contents on the sensory apparatus of the mucous membrane. This reflex may be increased (1) by anything that induces irritation of the mucous surface and thus renders it more sensitive to the pressure of the contents, and (2) by increasing the bulk of the contents until they exert more pressure on the mucous surface. The accelerated peristalsis after the vegetable and mercurial purgatives is due to their irritating the mucous membrane, while the purgation of the saline cathartics (p. 105) arises from their increasing the bulk of the contents. In neither case is there any reason to suppose that the neuro-muscular apparatus of the bowel is directly affected by the drugs; nor is the central nervous system implicated in the reflex whether normal or exaggerated by the purgatives.

In small quantities, such as are used in the vast majority of cases in therapeutics, the irritation produced by the vegetable purgatives is apparently only enough to accelerate peristalsis, and the fluid of the stools is drawn partly from the food and partly from the ordinary secretions of the digestive organs. In these cases the intestine is not actually inflamed, although some congestion may occur in it, as in all organs in a state of abnormal activity. On the other hand, when large quantities are ingested a true inflammation of the intestine occurs, manifested by increased movement, congestion, exudation of fluid into the lumen of the bowel, and pain. In these cases the intestine presents the usual signs of inflammation; it is red and congested, and contains a muco-purulent fluid and often blood. The origin of the fluid of the stools thus varies with the dose of purgative used; if it be small, the fluid is not an exudate, if it be large the fluid is partly an inflammatory product. The stools following the administration of purgatives differ from the normal faces in containing a larger proportion of water and also of soluble substances. In fact, they resemble rather the contents of the small intestine than the normal excreta, and contain bodies which would normally have been absorbed and utilized, but which have been hurried through the bowel too rapidly to permit of their being taken up by the epithelium.

The colic produced by purgatives is not due to the inflammation of the intestinal wall, but is explained by the more vigorous contractions of the walls of the bowel and the compression of the mucous membrane between the muscle and hard fæcal masses in the large intestine. The tenderness produced by large quantities of the purgatives, on the other hand, would seem to indicate inflammation.

The different purgatives seem to act on different parts of the bowel (Magnus). Thus senna, and in all probability the other anthracene purgatives, appear to have no effect on the movements of the stomach and small intestine, but act only in the large intestine; the contents reach the colon at the normal rate, but as soon as they have left the small bowel, rapid movement begins and they are evacuated almost immediately. Castor oil on the other hand accelerates the peristalsis of the small intestine, through which the food passes very rapidly, while the large gut is much less irritated. Colocynth quickens the movement of both small and large intestine and considerable quantities of fluid are effused into the lumen. All three arrest the antiperistaltic movements in the large intestine.

Some of the purgatives cause evacuation of the bowel when they are injected subcutaneously or intravenously (senna, aloes, cascara, colocynth, podophyllum), and croton oil has long been rubbed on the skin in order to relieve constipation, and is found to cause intestinal inflammation and purging when injected intravenously. It has accordingly been suggested that these have a specific action on the bowel quite apart from their irritant effects; but it is probable that their intestinal effects are here due to their excretion into the bowel, which has been shown to occur in several instances. Other irritants applied subcutaneously or intravenously often produce similar effects on the alimentary canal.

The interval which elapses between the administration of a purgative and its effects varies with the dose, and also with the individual drug. In ordinary therapeutic doses, evacuation of the bowels occurs in most cases in five to ten hours, but if large quantities of the more powerful purges, such as jalap or croton oil, be given, the effects may be elicited in two hours. Aloes, cascara and podophyllum differ from the others in the length of the interval, catharsis rarely or never occurring earlier than ten to twelve hours after their administration, and often only after twenty to twenty-four hours.

The movement of the intestine induced by purgatives is accompanied by an increase in the leucocytes of the blood similar to that observed in other forms of intestinal activity, *e. g.*, during digestion.

The effects of the purgatives vary greatly in different animals. Thus, the rabbit is very refractory to most of the series, and often is killed by intestinal irritation without any evacuation being produced. The frog is unaffected by quantities which would produce poisoning in man, while the dog and cat respond much more readily.

It was formerly supposed that purgatives increased the secretion of bile, and certain of them, which were believed to have a special activity in this direction, were known as *Cholagogues*. It has been shown of recent years that none of them possesses any action on the secretion of bile, although they may increase its excretion by hurrying it through the intestine and preventing its reabsorption. On the other hand, the presence of bile in the intestine is a condition necessary to the activity of many of the purgatives. Thus Buchheim and Stadelmann found that in the absence of bile podophyllum, jalap, scammony, rhubarb, and gamboge are either quite inactive or very much less powerful than usual. This is probably due to some solvent action of the bile, for Stadelmann found that when soaps were given with some of these drugs their activity returned, and in other cases a comparatively slight modification of their chemical form was sufficient to restore their activity, even in the absence of either bile or soap. Analogous results have been observed from other causes than the absence of bile; thus some of the pure principles of the purgatives are much less active than the crude drugs because the impurities of the latter alter their solubility. This alteration of the solubility may act in two ways: if the principle is rendered too soluble, it may be absorbed in the stomach and upper part of the bowel, and therefore fail to produce purgation; on the other hand, it may be rendered so insoluble that it fails to come into intimate contact with the bowel wall, and therefore does not irritate it. The effect of such colloid substances as the bile and gums is to delay the absorption of soluble substances in the upper part of the bowel and at the same time to keep the insoluble resins in suspension.

Few of the purgatives have any appreciable action after absorption, but general effects may be produced indirectly from their intestinal action. It is probable that reflexes are elicited by irritation of the bowel analogous to those discussed under skin irritants, but in addition, the congestion of the bowel produced by its activity must alter con-

siderably the distribution of the blood in the body. The belief in the efficacy of a purge in congestion of the brain may thus be based on a true "revulsive" action; for the dilatation of the intestinal vessels must necessarily lower the blood-pressure and thereby lessen the blood supply to the brain. The congestion of the lower intestine is accompanied by a similar condition in the other pelvic organs, and those purgatives that act strongly on the large bowel, therefore often cause congestion of the uterus, with excessive menstrual flow, or in the case of pregnant women, abortion. Lastly, a certain amount of fluid is withdrawn which would otherwise be excreted by the urine, which is found to be proportionately diminished in amount.

1. Mild Aperients, the Castor Oil Group.

Castor Oil (Oleum Ricini) resembles olive oil in most respects, but on saponification forms ricinoleic acid instead of oleic acid. This acid ($C_{17}H_{32}$ (OH)COOH) differs from the fatty acids obtained from ordinary oils in being unsaturated and in containing a hydroxyl group. Castor oil is itself a bland, non-irritating fluid, but on passing into the intestine is saponified by the pancreatic juice, and the ricinoleates thus formed are irritant and cause purgation. When the oil is saponified and the free acid given by the mouth, the effects are quite different from those of the oil, for the taste is acrid and unpleasant, and discomfort, nausea and vomiting may follow its ingestion from its irritant action on the stomach. The oil, on the other hand, has a bland, if unpleasant, taste, and produces no effects on the stomach. Several other esters of ricinoleic acid have been shown by Meyer to resemble the glycerin ester (castor oil) in their purgative effects.

Castor oil is absorbed from the small intestine and thus does not act on the large intestine directly. In the tissues it disappears in the same way as an ordinary oil. It may be given in very large quantities without producing any symptoms, save those of a mild laxative, which induces evacuation in about six to ten hours. It is occasionally used as an emollient to the skin, and has been employed as a solvent for application to the eye. The harmless nature of castor oil is shown by its use in China as an article of diet.

In the beans from which castor oil is derived, a toxalbumin is found, which was at one time supposed to be the active principle of the oil. (See Ricin.) It has been shown, however, that the oil is entirely free from this poison, and that its action is due solely to the ricinoleate.

Oleum Ricini, a fixed oil expressed from the seed, or bean of Ricinus communis. Dose, U. S. P., 15 mils (4 fl. drs.); B. P., 1–8 fl. drs.

Castor oil is difficult to take owing to its unpleasant taste. It may be given alone, in an emulsion flavored with sugar and some volatile oil, in wine, spirits, or glycerin, or in flexible capsules.

Phenolphthalein, $C_6H_4<\begin{matrix}C(C_6H_4OH)_2\\ CO\end{matrix}>O$, a synthetic substance, has been used of late years as a mild aperient. It is very insoluble in water and is not irritant when applied to the ordinary mucous membranes.

In the bowel it is dissolved by the bile and alkali and develops a mild irritant action in the small intestine and more distinctly in the large one. Most of the phenolphthalein administered by the mouth is not absorbed but appears in the stools. A small amount undergoes absorption and is excreted by the kidney; if the urine is alkaline it is colored a brilliant pink. Phenolphthalein is practically not poisonous when injected intravenously in animals. It has a mild laxative effect when injected subcutaneously, and this arises from its being excreted into the bile and thus carried to the gut. In the large intestine it is reabsorbed into the blood and again carried to the liver and returned to the gut. It therefore acts for several days as a mild aperient, but as it is gradually eliminated in the urine and stools, the action passes off. Tetrachlorphenolphthalein acts in the same way as phenolphthalein but is excreted only by the bile when injected subcutaneously and thus acts for a longer time.

Phenolphthaleinum (U. S. P., B. P.), a crystalline powder, white or grayish-white, soluble in 600 parts of water or in 10 parts alcohol. The solution turns red when alkali is added. Dose, 0.15 G. (2½ grs.), in powder, pills, or capsules. It has been injected hypodermically in solution in olive oil.

Sulphur is in itself an inert body, but while much the greater portion escapes in the stools unchanged when it is swallowed, some of it forms sulphides in the mucous membrane of the intestine, and these cause irritation, especially in the large bowel, increased peristalsis and a soft, formed stool; in large quantities it has caused, in some instances, more severe symptoms with bloody evacuations. The sulphides form some hydrogen sulphide, which gives rise to eructation. Some 10–40 per cent. of the sulphur taken by the mouth is absorbed as sulphide, which is excreted to a small extent by the lungs, giving the characteristic disagreeable odor to the breath, and to a much larger extent by the urine as sulphates and in organic combination. Sulphur given by the mouth does not seem to change the nitrogenous metabolism as was believed at one time; but injected into muscle it is said to cause fever and to accelerate the protein waste.

Applied to the skin in ointment, sulphur appears to be formed in part to sulphide, particularly if some alkali be added; the sulphide is destructive to animal parasites and sulphur ointment has therefore been used in the treatment of scabies, but has been supplanted largely by balsam of Peru. It may also be of value in skin disease through the sulphides tending to soften and dissolve the horny epidermis. For this purpose it may be associated with salicylic acid.

The formation of sulphide in the intestine may perhaps explain the aperient action of some other drugs, such as powdered white mustard seed, which has long enjoyed a popular reputation in constipation (Van Leersum).

Preparations.

Sulphur Sublimatum (U. S. P., B. P.), Flowers of Sulphur, sublimed sulphur, and *Sulphur Lotum* (U. S. P.), washed Flowers of Sulphur, form fine yellow powders insoluble in water and very slightly soluble in alcohol.

Sulphur Præcipitatum (U. S. P., B. P.), Milk of Sulphur, is prepared from sulphide of calcium by precipitation and forms a fine, almost white powder.

Dose of all three preparations, U. S. P., 4 G. (60 grs.); B. P., 20–60 grs.

Unguentum Sulphuris (U. S. P., B. P.), formed from sublimed sulphur, which is also contained in the Compound Liquorice Powder.

Trochiscus Sulphuris (B. P.) contains 5 grs. of sulphur.

Crude sublimed sulphur often contains arsenic, but the B. P. preparation is practically free from it. The milk of sulphur is in a finer state of division than the flowers, and is said to be a somewhat more active aperient.

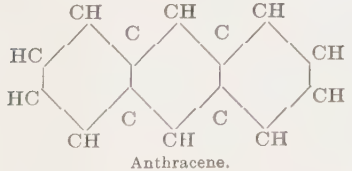
Glycerin.—When glycerin is injected into the rectum, it withdraws fluid from the mucous membrane and thus causes irritation, persistalsis, and evacuation of the bowels; the stool is of almost ordinary consistency, and no pain or colic is felt subsequently, nor does the remedy cause more than one evacuation. Glycerin may be injected into the rectum for this purpose (dose 2–5 mils, $\frac{1}{2}$–1 teaspoonful), but a more convenient form is the glycerin suppositories, **Suppositoria Glycerini**, which are made up with stearic acid and sodium carbonate, U. S. P., with gelatin, B. P. Glycerin suppositories are used in constipation instead of the ordinary aperients. Large doses of glycerin taken internally sometimes cause purgation, but it is not a reliable remedy when administered in this way. Instead of glycerin suppositories, small pieces of soap may be inserted in the rectum, and the same purpose may be served by the injection of a little strong soap solution in water.

Glycerin in large quantities is poisonous, whether it is taken by the mouth or injected hypodermically or intravenously. It is true that no case of glycerin poisoning in man is known, but large doses are fatal to animals in the course of a few hours. The chief symptoms are restlessness, agitation, acceleration of the heart and respiration, general weakness, tremor and convulsions, which finally end in somnolence, coma, and death from failure of the respiration. Glomerulonephritis has also been observed in animals. Glycerin is absorbed rapidly from the intestine, and undergoes combustion in the tissues, only a very small fraction of it reappearing in the urine.

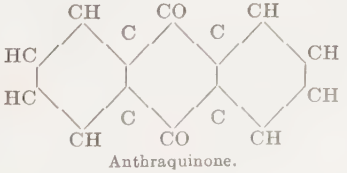
2. The Anthracene Purgatives.

A number of purgatives, *Rhubarb, Senna, Aloes, Cascara* and *Frangula*, owe their activity to the presence of irritant *anthracene* ($C_{14}H_{10}$) compounds. The chemical examination of these drugs is a matter of difficulty, as they often contain several active principles which are very nearly related to each other, and some of which are undoubtedly the products of the decomposition of more complex bodies.

All those which have been completely isolated hitherto have proved to be derivatives of anthraquinone,



Anthracene.



Anthraquinone.

and some of the oxyanthraquinones seem to be widely distributed. Thus all the members of the group contain *Emodins* or trioxymethylanthraquinone, ($C_{14}H_4(CH_3)(OH)_3O_2$), and several of them contain *Chrysophanol* or dixyomethylanthraquinone, ($C_{14}H_5(CH_3)(OH)_2O_2$). In addition, a number of other anthracene bodies occur in these purgatives, some of them combined with sugars to form glucosides, but little is known regarding them and hardly any of them are definitely established as pure substances. Among the names applied to these bodies are *cathartin* or *cathartic acid, frangulin, aloin,* but it is to be noted that the bodies designated by these names vary in character and are alternately asserted to be pure principles and composite mixtures by different investigators.

None of the pure principles are as satisfactory in their action as the crude drugs, perhaps because they are less soluble in the intestine. For example, *aloin* is less certain in its effects than aloes, and it seems to be indisputable that the crystalline aloin itself is inactive in the bowel, but is there changed under certain conditions to an amorphous compound which has irritant effects. The presence of bile in the intestine is not necessary to elicit the action of this group, except perhaps in the case of rhubarb.

The absorption of these bodies has not been satisfactorily determined in most cases. The urine is rendered yellow after rhubarb and senna, owing to the absorption and excretion of chrysophanol, but it is questionable whether the more active principles pass into the urine in appreciable amounts. When aloin is injected subcutaneously or intravenously, it is excreted for the main part into the bowel, and there produces irritation and catharsis. The yellow pigment of the urine after rhubarb and senna becomes a purple red on the addition of alkalies; the milk and skin also are said to assume a yellowish tinge from the presence of chrysophanol.

In the rabbit aloin seldom causes purgation, and is excreted by the kidney in considerable quantity, especially when injected hypodermically. In passing through this organ it causes marked irritation and epithelial necrosis, which often proves fatal in a few days. No irritation of the kidney occurs in man, the dog, or the cat after aloin. The anthracene purgatives have little action until they reach the large intestine, presumably because they do not find suitable conditions for solution in the small bowel. The interval between their administration and the evacuation of the bowel therefore tends to be longer than under most other purgatives; and for the same reason they tend to cause greater pelvi · congestion. Among them aloes is especially slow in action and tends to cause congestion of the uterus.

Rhubarb contains a considerable amount of tannic acid, which acts as an astringent and therefore tends to cause constipation after the evacuation of the bowels. It is not well tolerated in some cases, its administration being followed by nausea, headache and giddiness, more rarely by skin eruptions of different kinds. Senna preparations are generally found to have a greater tendency to produce griping than the other members of this series.

Preparations.

U. S. P.—**Rheum**, rhubarb, the rhizome of Rheum officinale and other species. 1 G. (15 grs.).

Extractum Rhei, 0.25 G. (4 grs.).

Fluidextractum Rhei, 1 mil (15 mins.).

Pilulæ Rhei Compositæ (aloes, myrrh, and oil of peppermint), 2 pills.

Pulvis Rhei Compositus (Gregory's Powder) contains magnesia and ginger. Dose, 2 G. (30 grs.).

Tinctura Rhei Aromatica (contains several volatile oils), 2 mils (30 mins.).

Syrupus Rhei Aromaticus. Dose, 10 mils (2½ fl. drs.).

B. P.—**Rhei Rhizoma**, rhubarb, the rhizome of Rheum palmatum; 3-10 grs. (0.2–0.6 G.) for repeated administration; for a single administration, 15–30 grs. (1–2 G.).

Pilula Rhei Composita (contains rhubarb, aloes, myrrh, and oil of peppermint), 4–8 grs. (0.2–0.5 G.).

Pulvis Rhei Compositus (Gregory's Powder) contains rhubarb, light magnesia and ginger, 10–60 grs. (1–4 G.).

Tinctura Rhei Composita, formed from rhubarb, cardamom and coriander, ½–1 fl. dr. (2–4 c.c.) for repeated administration; 2–4 fl. drs. (4–15 c.c.) for a single administration.

Syrupus Rhei, ½–2 fl. drs. (2–8 c.c.).

U. S. P.—**Senna**, the leaflets of Cassia acutifolia (Alexandria Senna), and of Cassia angustifolia (India Senna). 4 G. (1 dr.).

Fluidextractum Sennæ, 2 mils (30 mins.).

Infusum Sennæ Compositum (Black Draught) contains senna, manna, magnesium sulphate and fennel, 120 mils (4 fl. oz.).

Syrupus Sennæ, 4 mils (1 fl. dr.).

Senna is also contained in the compound syrup of sarsaparilla and in the compound liquorice powder.

Senna is often administered as a simple infusion, senna tea, a teaspoonful of the leaves being used in a cupful of water.

B. P.—**Senna**, the dried leaflets of Cassia acutifolia (Alexandrian senna), and of Cassia angustifolia (Tinnevelly senna).

Syrupus Sennæ, ½–2 fl. drs. (2–8 c.c.).

Infusum Sennæ, ½–1 fl. oz. (15–30 c.c.); as a draught, 2 fl. oz. (60 c.c.).

Mistura Sennæ Composita (Black Draught), formed from magnesium sulphate, liquorice, compound tincture of cardamom, aromatic spirit of ammonia, and infusion of senna, ½–2 fl. oz. (15–60 c.c.).

U. S. P. **Aloe**, the inspissated juice of the leaves of several species of aloe.

Aloinum, a pentoside or pentosides obtained from aloes, 0.015 G. (¼ gr.).

Pilulæ Aloes, 2 pills.

Tinctura Aloes, 2 mils (30 mins.).

Aloes is also contained in compound rhubarb pill, compound extract of colocynth, and compound tincture of benzoin.

B. P.—**Aloe**, the dried juice of Aloe chinensis and other species, 2–5 grs. (0.1–0.3 G.).

Extractum Aloes, 1–4 grs. (0.05–0.2 G.).

Pilula Aloes, 4–8 grs. (0.2–0.4 G.).

Pilula Aloes et Ferri, 4–8 grs. (0.2–0.4 G.).

Pilula Aloes et Asafœtidæ, 4–8 grs. (0.2–0.4 G.).

Aloes is also contained in the compound extract of colocynth, compound colocynth pill, pill of colocynth and hyoscyamus, compound tincture of benzoin and compound rhubarb pill.

U. S. P.—**Frangula**, Buckthorn, the bark of Rhamnus frangula.

Fluidextractum Frangulæ, 1 mil (15 mins.).

U. S. P.—**Cascara sagrada**, the bark of Rhamnus Purshiana.

Extractum Cascaræ Sagradæ, 0.25 G. (4 grs.).

Fluidextractum Cascaræ Sagradæ Aromaticum, 2 mils (30 mins.).
FLUIDEXTRACTUM CASCARÆ SAGRADÆ, 1 mil (15 mins.).
B. P.—**Cascara Sagrada**, the dried bark of Rhamnus Purshianus.
Extractum Cascaræ Sagradæ Siccum, 2–8 grs. (0.1–0.5 G.).
EXTRACTUM CASCARÆ SAGRADÆ LIQUIDUM, ½–1 fl. dr. (2–4 c.c.).
Syrupus Cascaræ Aromaticus, ½–2 fl. drs. (2–8 c.c.).
Two artificial compounds of oxyanthraquinone have been introduced under the name of *purgatin* and *exodin*, but have no advantages over the natural purgatives and the possibility of their inducing nephritis renders their use inadvisable.

Of these numerous preparations, the most extensively prescribed are the pills. The fluid preparations have an unpleasant, bitter taste, and are therefore less used, unless when disguised by the addition of sugar or volatile oils. The syrups of rhubarb and senna are often administered to children, and the confection of senna and the compound liquorice powder are also pleasant, easily taken preparations. The compound infusion or mixture of senna and the compound rhubarb powder are old and tried preparations, in which the virtues of the vegetable purgative are combined with those of a saline cathartic and antacid respectively; they are both possessed of a harsh, unpleasant taste. Frangula is comparatively rarely used, but the fluid extract of cascara sagrada, which is practically identical with it, is a very popular remedy in habitual constipation.

3. The Jalap and Colocynth Group.

The third group of the vegetable purgatives comprises a number of resinous glucosides and acids, whose more intimate chemical structure is unknown, though a number of them appear to be nearly related chemically, so that it is possible that they all contain a common radicle like the members of the anthracene group.

Jalap resin contains two anhydride glucosides, *Convolvulin* and *Jalapin*, the latter only in very small quantity. Scammony consists very largely of *Jalapin*. Elaterium contains *elaterin*, a very powerful purgative of which little is known. Podophyllum contains two isomeric principles, *Podophyllotoxin* and *Picropodophyllin*. Gamboge owes its activity to *Cambogic acid*, which, however, is insoluble, and seldom acts unless it is accompanied by the inactive bodies of the crude drug. *Colocynthin* is a glucoside occurring in the colocynth fruit, and forms *Colocynthein* and sugar when treated with acids; colocynthein is said to be even more irritant than colocynthin. Euonymus owes its activity to a resinous glucoside, *Euonymin*. Croton oil contains a resinous anhydride[1] dissolved in an inactive oil. The seeds from which the oil is obtained contain a poisonous protein, but this is not present in the oil. Many other plants contain similar resinous purgative substances, and some of these are used as remedies to some extent, but so little is known of their properties and they are so seldom employed that they may be omitted here.

[1] The action of croton oil is often stated to be due to crotonoleic acid derived from the oil in the same way as ricinoleic acid is obtained by the saponification of castor oil. This is incorrect, however, the croton resin which is the active principle of croton oil having no relation to the oil in which it is dissolved. Several other plants contain similar principles, *e. g.*, Jatropha curcas, which bears the Barbadoes nuts, or purging nuts, and Garcia nutans and several species of Omphalea (Cash).

Action.—These substances are in general much more powerful than any of the other purgatives, and are therefore classed together as the drastic purgatives or hydragogue cathartics. In small quantities they cause evacuation more rapidly than the anthracene purgatives, and in somewhat larger doses produce profuse watery stools with much pain and often tenesmus. In cases of poisoning, the bowel undergoes acute inflammation, and blood is passed in the stools, which often contain shreds of epithelium from the walls. The irritant action is not confined to the bowel apparently, for their administration is sometimes followed by uneasiness in the stomach, and occasionally by nausea and vomiting. On the other hand, moderate quantities are said not to induce colic so frequently as some of the anthracene purges. This is probably due to the fact that they accelerate the movement of both the small and large bowel; a quantity of unabsorbed fluid is thus poured into the cæcum and the contents are rendered softer and more easily moved than if these drugs like the anthracene group acted only on the large intestine.

Several of these resinous purges are irritant to the skin and especially to the mucous membranes of the eye, nose, and throat. Thus jalap, podophyllum and colocynthin all cause pain and irritation when they are applied to the nostrils in fine powder, and croton oil and podophyllum have been used as skin irritants.

The presence of bile in the intestine increases the purgative action of almost all these bodies, and in fact, seems essential for the action of most of them.

Podophyllotoxin and colocynthin cause purgation when injected subcutaneously; this is probably owing to their excretion into the bowel, as the former has been detected in the fæces after this method of administration. Podophyllotoxin causes glomerular nephritis and hæmorrhages into various organs when administered hypodermically or intravenously in large quantities, and when added to blood in a test-tube, it causes the formation of methæmoglobin in the corpuscles. It has been said to have a depressant action on the central nervous system, but this is probably a result of the shock and hæmorrhage produced by its intestinal action. Colocynthin is said to cause renal inflammation when applied subcutaneously or taken internally, and even when the powder is inhaled during its manufacture. Jalapin and convolvulin given by the mouth are found in the fæces in a partially decomposed state; none appears in the urine.

Preparations.

Colocynthis (U. S. P.), **Colocynthidis Pulpa** (B. P.), colocynth, the pulp of the fruit of Citrullus Colocynthis deprived of its rind.

Extractum Colocynthidis (U. S. P.), 0.03 G. ($\frac{1}{2}$ gr.).

Extractum Colocynthidis Compositum (U. S. P., B. P.) (containing colocynth, aloes, scammony and cardamom), 0.25 G. (4 grs.).

Pilulæ Catharticæ Compositæ (U. S. P.) (compound extract of colocynth, jalap, gamboge, and calomel), 2 pills.

Pilula Colocynthidis Composita (B. P.) (colocynth, aloes, scammony resin, potassium sulphate and oil of cloves), 4–8 grs.

Pilula Colocynthidis et Hyoscyami (B. P.) (compound pill of colocynth and extract of hyoscyamus), 4–8 grs.

Oleum Tiglii (U. S. P.), **Oleum Crotonis** (B. P.), a fixed oil expressed from the seed of Croton Tiglium. 0.05 c.c. (1 min.).

Podophyllum (U. S. P.), **Podophylli Rhizoma** (B. P.), the rhizome and roots of Podophyllum peltatum, may apple.

Fluidextractum Podophylli (U. S. P.), 0.5 c.c. (8 mins.).

Resina Podophylli (U. S. P., B. P.), 0.01 G. ($\frac{1}{6}$ gr.); B. P., $\frac{1}{4}$–1 gr.

Podophyllin varies considerably in composition, and ought to be avoided.

Jalapa (U. S. P., B. P.), the tuberous root of Exogonium Purga (U. S. P.), of Ipomœa Purga (B. P.). 0.3–1 G. (5–15 grs.).

Resina Jalapæ (U. S. P., B. P.), 0.125 G. (2 grs.); 2–5 grs., B. P.

Pulvis Jalapæ Compositus (U. S. P., B. P.) contains jalap and bitartrate of potassium. 2 G. (30 grs.); 10–60 grs., B. P.

Scammoniæ Radix (U. S. P., B. P.), Scammony root, the dried root of Convolvulus Scammonia.

Scammoniæ Resina (U. S. P., B. P.), 0.2 G. (3 grs.); 4–8 grs., B. P.

Scammony is contained in the compound colocynth preparations.

Elaterinum (U. S. P.), $C_{20}H_{28}O_5$, a neutral principle obtained from elaterium, a substance deposited by the juice of the fruit of Ecballium Elaterium (squirting cucumber). 0.003 G. ($\frac{1}{20}$ gr.).

Trituratio Elaterini (U. S. P.) (one part elaterin in 9 parts sugar of milk), 0.03 G. ($\frac{1}{2}$ gr.).

Cambogia (U. S. P.), Gamboge, a gum resin obtained from Garcinia Hanburii. Dose, 0.125 G. (2 grs.).

The resinous purgatives are generally administered in pill form; very frequently two or more are combined in one pill, or they may be prescribed along with extract of belladonna or hyoscyamus, or with a drop of some carminative oil or resin, to prevent the pain and griping which often accompanies their action. Croton oil is often given in a pill made up with breadcrumb, or a single drop may be given on a lump of sugar or in solution in castor oil. The importance of these purgatives is much less than it was formerly, and several of them are very seldom used; the most important are colocynth, podophyllum, croton oil, and jalap. In large doses they act rapidly, with the exception of podophyllum, which induces purgation very slowly (ten to twenty hours).

Therapeutic Uses of the Purgatives.—The purgatives are employed to cause evacuation of the bowel when for any reason its peristalsis is slow. In the choice of a purgative, the advantages of the vegetable purgatives must be weighed against those of the saline cathartics and of the mercurial preparations. In ordinary constipation of short standing, in which the peristalsis may merely seem somewhat more sluggish than usual, the milder laxatives are prescribed — castor oil, sulphur, senna, rhubarb, aloes, frangula, or cascara sagrada. The first two cause least disturbance of the bowel, but are disagreeable to take, and are less commonly prescribed for adults than rhubarb or cascara, or small doses of colocynth or podophyllum. In children or in debility in adults, senna and castor oil are frequently used; sulphur is often given along with magnesia in constipation in children, and in hæmorrhoids in which it is often beneficial, not owing to any specific action on the hæmorrhoids but because it renders the stools softer and less liable to cause irritation mechanically.

In chronic constipation which cannot be controlled by hygienic measures, or by the use of a special dietary such as fruits, or coarse meal, and where the intestine has apparently taken on a sluggish

habit, rhubarb, cascara, aloes, phenolphthalein, or colocynth may be ordered, but the saline cathartics often prove more satisfactory. Rhubarb tends to cause some constipation after its laxative effects, but is often used in these cases, as it possesses some bitter stomachic action, which compensates for its astringent after-effects. This bitter action is often given to the other purgatives by the addition of gentian, nux vomica, or cinchona. In obstinate constipation, in which the bowel contains hard fæcal masses, the milder purgatives often provoke griping without relieving the condition, and in these cases larger doses of colocynth, jalap, podophyllum, or croton oil are used, along with some of the extracts of the atropine group or with a carminative oil. They may be prescribed along with some of the saline cathartics, as in the compound infusion of senna or the compound powder of jalap.

Croton oil is used especially where the drug is required to be of small bulk and the administration is attended with special difficulty; thus in unconsciousness or mania, one or two drops may be given on sugar. In lead colic, croton oil is said to act more rapidly and efficiently than the others.

In some forms of diarrhœa constant irritation seems to be kept up by the presence of irritants in the bowel, and the indications are the removal of these by a purge rather than the administration of astringents. Castor oil, senna and rhubarb are especially adapted for this purpose; the first two because they increase the irritation of the bowel less than the others, the latter because of its subsequent astringent action.

A purgative is often administered as a preliminary in the treatment of malaria, syphilis and other conditions, and seems to have beneficial effects, although these are difficult to explain. In the beginning of acute fevers also, a purge is often useful, perhaps through the congestion of the bowel withdrawing the blood from the rest of the body, or through the removal of poisonous substances formed by the decomposition of the intestinal contents. In congestion of the brain and in high blood-pressure a purgative is often administered with good effects, which may also be attributed to the accumulation of blood in the mesenteric circulation, to the actually lessened bulk of the blood, and perhaps to some action analogous to counter-irritation of the skin. For these purposes a sharp purge is generally used, such as croton oil or some other of the jalap and colocynth series.

The more powerful purgatives, especially elaterin, were formerly largely used to remove fluid from the body in cases of dropsy or œdema, and they were generally prescribed along with the saline cathartics for this purpose. Other means, such as diuretics, are generally preferred now from a fear that the violent purging may weaken the patient, but good results are often obtained by means of this treatment, especially as a preliminary to the use of digitalis.

The congestion of the pelvic organs attending the purgative action of aloes has led to its use in amenorrhœa; it is generally administered along with iron which improves the condition of the blood.

The purges act as intestinal disinfectants by removing the micro-organisms mechanically, though the vegetable purges are less used for this purpose than calomel. A purgative is administered to remove poisons in the intestine when they have passed beyond the stomach or when they are excreted into the bowel.

Purgatives are contra-indicated in conditions of acute intestinal irritation and intestinal obstruction and during menstruation and pregnancy, owing to the congestion of the pelvic organs, which may lead to an excessive flow in the one case and to abortion in the other; aloes is especially dangerous in these conditions. In collapse, asthenia and anæmia, powerful purgatives are contra-indicated, owing to the irritation they produce. In hæmorrhoids, aloes is often said to do harm by increasing the congestion of the rectum, and powerful purges are injurious from the straining they cause, but if constipation is present, a mild purgative is beneficial. In all those conditions, if a purgative is required, either castor oil, senna, or rhubarb ought to be chosen.

Repeated attempts have been made to produce evacuation of the bowels by substances injected subcutaneously, but the ordinary purgatives are not suitable as they cause intense pain at the seat of injection. Physostigmine has been employed frequently, and more recently tetrachlorphenolphthalein has been used by Abel and Rowntree in solution in oil.

Another method by which the purgatives may be administered is in enema. The addition of purgatives, such as castor oil, and of bile to the ordinary enemata has been practised for many years, and small quantities of other purgatives have occasionally been employed in oil or glycerin.

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IX. MERCURIAL PURGATIVES.

The general action of mercury will be described later, but its purgative effects may be given here. The soluble preparations of mercury and even those which are insoluble but are readily changed to soluble forms are too irritant to the stomach to be employed for their action on the bowel. But certain preparations pass through the stomach in an insoluble form and slowly unfold a mild irritant action on the bowel mucous membrane, and, rendering it more sensitive to the presence of its contents, increase the peristalsis in the same way as the vegetable purgatives. Calomel is more widely used as a purgative now, than any other mercurial, but the metallic preparations have also a certain vogue for this purpose.

These preparations pass through the stomach unchanged, and presumably form some protein combination in the mucous membranes of the intestine, but its nature is quite unknown. Only a limited proportion of the calomel administered seems to enter into this combination, for much can be regained from the stool in an inorganic form. And though the action on the bowel is greater after large doses, it never becomes excessive, no marked poisoning occurring from calomel, such as arises from the soluble salts of mercury. A certain amount is absorbed into the tissues and is finally excreted in the urine, but in ordinary conditions this is small. But when calomel fails to evacuate the bowel, absorption may occur in larger measure, and severe poisoning is said to have followed.

Small doses generally cause a soft stool without pain or straining, but after larger amounts a considerable amount of fluid may appear in it. The stools are often of a gray-green color and this has been attributed to the putrefaction of the bowel being lessened, so that the bile retains its original tint. But mercury acts when no bile reaches the intestine and the stools are of the same greenish color, so that it seems likely that this arises from the presence of some mixture of mercury sulphides in the stool.

Mercury accelerates peristalsis in the small intestine, the contents

passing from the stomach to the cæcum in about half the ordinary time, but its chief effect is in the large bowel which may be traversed about four times as fast as usual.[1]

It is often credited with some disinfectant action in the bowel, but this is probably slight, and the removal of the contents may probably be more efficacious than any attempt at their disinfection.

The mercurial purges, and in particular calomel, have often been credited with increasing the secretion of the **Bile**, but this has been shown to be incorrect, for Stadelmann (in animals) and Pfaff (in man) found that they had no effect on the secretion escaping from a biliary fistula. There is, in fact, no sufficient experimental or clinical evidence that the liver is in any way affected directly by mercury. The "biliousness" which is so often relieved by calomel or blue pill, is due, not to the liver, but to disorder of the alimentary tract.

Hydrargyri Chloridum Mite (U. S. P.), Hydrargyri Subchloridum (B. P.), mild mercurous chloride, CALOMEL (Hg_2Cl_2), a heavy white powder, without odor or taste, insoluble in water, alcohol and ether. 0.015–0.15 G. ($\frac{1}{4}$–$2\frac{1}{2}$ grs.); B. P., $\frac{1}{2}$–5 grs., in powder or tablets, less suitably in pill form.

Calomel is contained in the compound cathartic pill U. S. P. (p. 99).

Hydrargyrum cum Creta (U. S. P., B. P.), mercury with chalk, GRAY POWDER, is formed by rubbing up metallic mercury with chalk and honey (U. S. P.) until the mercury is divided into very fine globules, each encased in chalk. It forms a light-gray, somewhat damp powder, without odor and with a sweetish taste from the honey. The mercury (38 per cent. U. S. P., 33 per cent. B. P.) remains in the metallic state, very little oxide being formed. It is insoluble in water, alcohol and ether, and is always prescribed in powder form. 0.25 G. (4 gr.); B. P., 1–5 grs.

Massa Hydrargyri (U. S. P.), mass of mercury, BLUE MASS, BLUE PILL, is formed from metallic mercury by rubbing it with Mel Rosæ, glycerin, althæa and liquorice until the globules are invisible under a lens magnifying ten diameters. The blue mass contains about 33 per cent. of mercury almost entirely in the metallic form. It is of the consistency of pills and is always prescribed in this form. 0.25 G. (4 grs.).

Pilula Hydrargyri, BLUE PILL, the corresponding B. P. preparation, is made up with confection of roses and liquorice by rubbing them with metallic mercury until the globules are no longer visible. 4–8 grs.

Therapeutic Uses.—The mercurials are largely used as occasional purgatives for acute constipation, not so frequently in chronic constipation. In "biliousness" and in the diarrhœa of putrefaction they have a high reputation, but their action here is not materially different from that of other purgatives. There is no evidence that they are of value when the intestinal wall itself is the seat of infection. They cause less discomfort and colic than most other purgatives and small doses are followed by only one evacuation. They may therefore be given where preëxisting irritation contra-indicates the use of most other purgatives. They are often advised in affections of the liver but it is a question whether they have any effect here except as purges. Calomel and gray powder are especially adapted for children and are of value in summer diarrhœa and similar affections. They are quite tasteless and are easily

[1] *Willigen.* Pflüger's Archiv., clxxxvi, p. 185.

taken in sugar or jam. Very often a mercurial is taken at night and is followed in the morning with a saline purgative such as Seidlitz powder.

Calomel should be avoided in nephritis and is said to be dangerous when iodides are being given since the poisonous periodide of mercury may be formed.

X. SALINE CATHARTICS.

Dilute solutions of such salts as the chlorides, iodides, and bromides of the alkalies are absorbed rapidly from the alimentary canal, but some of the other salts of these metals apparently permeate the epithelium with greater difficulty, and their solutions therefore remain unabsorbed for a longer time in the intestine. The contents of the intestine and the stools thus contain more fluid than usual and these salts are known as the saline cathartics. The chief salts of sodium and potassium which have this intestinal action are the sulphates, phosphates, tartrates and citrates; less known ones are the malates and ferrocyanides.

In these effects the acid constituent, or anion, is obviously the chief factor, for the same base, or cation, is present in readily absorbed salts such as the chlorides. And no pronounced differences between the action of chlorides and sulphates are observed, unless the salt can be given in large quantities, as is possible in the case of the salts of the alkalies. The effects of the sulphate and hydrochlorate of morphine, for example, may be taken as identical, because the anion is present in so small amount as to be practically inert.

The cation of a salt may also fail to be taken up readily by the bowel; for example, magnesium chloride is absorbed slowly although other chlorides permeate rapidly, and magnesium salts thus act as purgatives in the same way as sulphates. When both ions are slowly absorbed, as in the case of magnesium sulphate, the cathartic action is naturally more powerful than when only one has this character.

The chief saline cathartics used in therapeutics are the *sulphate of sodium* (Glauber's salt), the *sulphate of magnesium* (Epsom salt), the *double tartrate of sodium and potassium* (Rochelle salt) and the *phosphate of sodium*. In addition the *oxide* and *carbonate of magnesium* have some purgative action from being formed into soluble salts in the stomach and intestine. But besides these, many other salts are slowly absorbed and might therefore be used for this purpose. Thus the sulphates, citrates, or tartrates, of any of the alkalies or of the non-poisonous alkaloids might be substituted, provided they are soluble, and any of the magnesium salts might be employed in the same way.

Symptoms.—The external application of solutions of the saline cathartics has the same effect as that of any other indifferent salts, such as sodium chloride.

Most of the cathartics have a harsh, bitter, unpleasant taste, and when taken in concentrated solution, may induce some nausea, partly from the taste, and partly from the "salt-action" on the stomach, which they possess like other soluble bodies. Dilute solutions, however,

provoke no such symptoms, but after one or two hours induce a profuse watery evacuation of the bowels. This is sometimes preceded by some pain and griping, but these are not nearly so frequent or so severe as after the vegetable purgatives. Not infrequently the urine is increased in amount afterward, or it may be found to have an unusually high percentage of salts. If a moderate quantity of a dilute solution be given, only one evacuation follows, but large doses of concentrated solutions induce repeated stools, which at first contain some fæcal matter, but later consist mainly of bile-stained mucous fluid.

Action: Intestine.—The saline cathartics differ from the vegetable purgatives in not inducing irritation of the intestine, unless when they are given in very large quantities. The characteristic effect is not irritation, but retarded absorption. The slow absorption of the salt entails the slow absorption of the fluid in which it is dissolved, for the salt holds on to the water and only permits of its being taken up by the bowel if an equivalent amount of salt is also absorbed. If a solution of sodium chloride isotonic with the blood serum be administered by the mouth to a dog with a cæcal fistula, little or none of it reaches the wound, as it is all absorbed in the stomach and small intestine. If, on the other hand, an equal amount of an isotonic solution of sodium sulphate be administered in the same way, most of the solution escapes by the fistula, only some 10–20 per cent. having been absorbed by the stomach and small intestine. In a normal dog or in the human subject, a much larger amount of fluid therefore reaches the large intestine if sodium sulphate be dissolved in it than if sodium chloride be used instead. The contents of the large intestine are consequently more fluid than usual, and are passed down more easily toward the rectum. At the same time the weight and distention of the bowel induces increased peristalsis and the whole is evacuated. This increased peristalsis is due, however, not to any irritant action such as has been found to be induced by rhubarb or croton oil, but to the large amount of fluid contents, which arouses the usual peristaltic reflex (p. 90).

This accelerated passage along the bowel has been observed in man by means of the Röntgen rays, and appears to resemble that previously described in animals. When the distended small intestine empties its contents into the colon, the large bowel adopts a more rapid but otherwise normal movement and this leads to the evacuation of the rectum; the first stool may thus be of almost normal consistency, but this is generally followed by a profuse watery movement which may contain the greater part of the salt administered.

If a weaker solution of sodium sulphate is administered, the only difference is that more of the fluid is absorbed and less reaches the large intestine; but however weak the solution, more of it reaches the large intestine than if a correspondingly weak solution of common salt had been given.

If a hypertonic solution be administered, the effect is somewhat different. The salt is still unabsorbed, but it draws fluid from the blood into the bowel from its having higher osmotic pressure than the

blood. A similar draining of the body fluids occurs when concentrated solutions of common salt reach the bowel, but the cathartic salts are much more powerful, because they do not pass out of the bowel into the blood so easily. Instead of an exchange of salt and fluid being carried on between the blood and intestinal contents, the blood gives up its fluid without any sufficient compensation in salt. Eventually the intestinal fluid becomes isotonic, and then some absorption of both salt and fluid occurs; in fact, some salt has been absorbed all along, as the epithelium is not absolutely impermeable to the cathartics. But much less of the sulphate is absorbed than of the chloride given in equal concentration, and as a general rule a strong solution causes such an accumulation of fluid that the bowel becomes distended and evacuates its contents. If, however, from any cause this fails to occur, a gradual absorption follows and the whole salt and fluid in the bowel is absorbed. These salts may fail to purge, for example, when the blood and tissues contain very little fluid, as in animals which have been deprived of water for several days previously. In this case the osmotic pressure in the bowel is unable to draw fluid from the concentrated blood, which on the other hand has a higher attraction for the fluid in the bowel than usual. But where large quantities of fluid are present in the tissues, as in œdema and dropsy, the saline cathartics drain them through the blood into the bowel, and very profuse evacuation occurs, with the disappearance of the exudate.

The saline cathartics fail to penetrate the intestinal epithelium, just as sodium chloride fails to penetrate the blood corpuscles (p. 26), through some peculiar physical character, which prevents them following the ordinary process of diffusion and which is at present unknown. In this relation it has been found by Hofmeister and Pauli that the purgative salts have a greater tendency to precipitate proteins and have less tendency to permeate into unorganized colloids than most of the non-purgative salts. In numerous other instances the sulphates, tartrates, and other cathartic anions have proved slower in permeating into living cells than the chlorides and bromides, and their effects on the blood cells, muscle, nerve, and some other tissues show marked deviations from those of the halogen salts. Another curious relation between the purgative anions is that their calcium salts are all much less soluble than those of the salts which penetrate the epithelium, and it seems possible that they precipitate the calcium in the bowel wall. Most of the cathartic anions are bivalent or trivalent, but this is not true for all of them, for the higher members of the acetate series are absorbed with the greatest difficulty by the intestine.

The saline cathartics induce certain changes in the **Blood** indirectly through their action on the intestine. They prevent the absorption of the fluid of the food, or, if in sufficient concentration, actually draw fluid from the blood and tissues into the bowel, and under both conditions the blood becomes more concentrated than usual; in the first case because it is not reinforced by the usual amount of fluid from the food, in the second because it actually loses fluid into the intestine.

This concentration of the blood leads to a sensation of thirst, and to a lessened excretion of fluid by the kidneys and other glands.

A certain amount of salt and of fluid is absorbed from the intestine, unless purgation follows very rapidly, and this salt acts in the blood and tissues in the same way as the salts which do not act as cathartics. When very dilute solutions of these salts are given, therefore, the blood becomes less concentrated and diuresis follows, but this does not occur so soon as after a similar solution of common salt, because the absorption is somewhat slower. Stronger cathartic solutions at first cause a concentration of the blood and lessened urine, but afterward the excess of salt in the blood may cause diuresis. The greater the purgative action, the less the diuretic, because more fluid and more of the cathartics are thrown out in the stools. If no purgation follows for any reason, as when the blood has been concentrated by long abstinence from water, the whole of the salt eventually passes into the blood and is excreted by the kidney, and may cause very considerable diuresis and a still further concentration of the blood. The sulphates are absorbed by the epithelium of the renal tubules with much greater difficulty than chloride, and thus offer osmotic resistance to the absorption of the fluid in the tubules; sulphates absorbed into the blood therefore induce a more profuse diuresis than an equal amount of chloride, but less of the former reaches the blood generally, so that the chlorides are better practical diuretics.

From the above it can be inferred at once that a saline cathartic injected intravenously causes no purgation, for instead of preventing the passage of fluid from the bowel into the blood, it rather encourages its absorption by increasing the osmotic pressure of the blood. And similarly the hypodermic injection of these salts is not followed by purging.

The statement is sometimes made that the saline cathartics act as cholagogues, *i. e.*, increase the secretion of bile, but this has not been confirmed by more careful observations.

The **Temperature** is often somewhat reduced by the action of the saline cathartics, but seldom more than one-half degree.

The habitual use of saline cathartics is often efficient in **Reducing the Weight** in obesity, and many of the natural mineral waters have a considerable reputation in the treatment of such cases. This appears to be due in part to less proteins and fats being absorbed from the intestine, in part to the fluids of the body being decreased. There seems no reason to suppose that any marked change in the nitrogenous metabolism is induced by the cathartics, for the nitrogen in the urine is often practically unaltered in amount.

Hay pointed out the curious fact that magnesium sulphate tends to lessen the alkali reserve of the tissues, owing to some sulphate being absorbed in combination with alkali, while the magnesium passes onward in the bowel in the form of carbonate; the sodium sulphate is then excreted in the urine and thus the body loses some of its alkali. The acidity of the urine depends on the content of sodium acid phosphate

(NaH_2PO_4), and in the absence of this salt the urine may be almost neutral; when it is desired to increase the acidity of the urine, this salt is employed.

When purgation follows the administration of a saline cathartic, the most of the salt escapes in the faeces, never having been absorbed at all. When the salt fails to purge, however, and is absorbed, it undergoes the usual exchanges in the tissues and is excreted by the urine. There is no reason to suppose that any of it appears again in the stomach or intestine.

The **Sulphates** seem to pass through the tissues without injuring them, and but little effect is observed from injecting considerable quantities into the blood. When the sulphate ion is combined with a poisonous base, such as potassium or magnesium, the injection is of course followed by characteristic symptoms; but the anion seems to be comparatively harmless, and when the potassium or magnesium salt is taken by the mouth it also is quite devoid of general action. A trace of sulphide is sometimes formed in the bowel from sulphate given by the mouth.

The **Phosphates** are also very inactive after absorption. When they are injected subcutaneously or intravenously, the metaphosphates and pyrophosphates are poisonous, but this appears to be due to their alkalinity (Starkenstein). Phosphates absorbed in man and in the carnivora are excreted by the kidney and increase the acidity of the urine; in the herbivora they are excreted exclusively by the bowel wall.

The **Tartrates** are slowly oxidized in the tissues to carbonates but a considerable quantity is excreted in the urine unchanged. Injected into the blood directly, the tartrates seem to act as heart poisons, and in the rabbit nephritis is induced by their hypodermic application, but no such effects are observed in man from their administration by the mouth even in enormous quantities.

The oxide and carbonate of magnesium differ from the other saline cathartics in being very insoluble and in possessing an alkaline reaction. Part of that ingested is formed into magnesium chloride in the stomach, however, and the carbonic acid present in the intestine may dissolve part by forming the bicarbonate. Their alkalinity serves to remedy any excessive acidity of the stomach or intestine, while at the same time they are mildly cathartic. The prolonged use of large quantities of magnesia has in some cases led to the formation of large concretions in the bowel, resulting in obstruction.

Preparations.

Sodii Sulphas (U. S. P., B. P.), Glauber's salt (Na_2SO_4, $10H_2O$), soluble in about 3 parts of cold water, 15 G. (4 drs.).

Magnesii Sulphas (U. S. P., B. P.), Epsom salts ($MgSO_4$, $7H_2O$), soluble in $1\frac{1}{2}$ parts of cold water, 15 G. (4 drs.).

These are crystalline salts with a harsh, bitter taste.

Sodii Phosphas (U. S. P., B. P.) ($Na_2HPO_4 + 12H_2O$), a crystalline salt with a cool, saline taste, soluble in about 6 parts of cold water, 4 G. (1 dr.).

Potassii Bitartras (U. S. P.), *Potassii Tartras Acidus* (B. P.), cream of tartar ($KHC_4H_4O_6$), a crystalline powder with a pleasant acidulous taste, soluble in 200 parts of water, 2 G. (30 grs.).

Potassii et Sodii Tartras (U. S. P., B. P.), Rochelle salt ($KNaC_4H_4O_6 + 4H_2O$), crystals or powder with a cool saline taste, soluble in 1.2 parts of cold water, 10 G. (2½ drs.).

Magnesia (B. P.), Magnesii Oxidum (U. S. P.), magnesia (MgO). 2 G. (30 grs.); B. P., 5–60 grs.

Magnesii Carbonas (U. S. P., B. P.), a mixture of carbonate and hydrate of magnesium. 3 G. (45 grs.).

These form white amorphous powders with an earthy, not saline, taste. They are insoluble in water, but the carbonate is dissolved by excess of carbonic acid.

Effervescing Preparations.

Pulvis Effervescens Compositus (U. S. P.), Pulvis Sodæ Tartaratæ Effervescens (B. P.), Seidlitz powder.

This powder is made up in two papers, of which the blue one contains a mixture of 3 parts of Rochelle salts and one part of sodium bicarbonate, in all 10 G. (160 grs.), while the white paper contains 2.2 G. (2.5 G., B. P.) of tartaric acid. When the powders are dissolved separately in water and the solutions mixed, the tartaric acid acting on the bicarbonate releases carbonic acid with effervescence.

Liquor Magnesii Citratis (U. S. P.) is a solution of magnesium citrate with excess of citric acid to which potassium bicarbonate is added. The whole is bottled tightly and effervesces when the cork is removed. 350 mils (12 fl. oz.),

Magnesii Sulphas Effervescens (B. P.), a mixture of Epsom salts, sodium bicarbonate, tartaric, and citric acids, which effervesces when mixed with water. 60–180 grs. (4–12 G.) for repeated administration; for a single administration ½–1 oz. (15–30 G.).

Sodii Sulphas Effervescens (B. P.), a similar mixture containing the sulphate of soda instead of that of magnesia. 60–120 grs. (4–8 G.) for repeated administration; for a single administration ¼–½ oz. (8–15 G.).

Sodii Phosphas Effervescens (B. P., U. S. P.), similar to the above, but containing the phosphate in place of the sulphate. 10 G. (2½ drs.).

Many other effervescent mixtures are used instead of the official ones—among them the tartrates and citrates of the alkalies, the acetate of magnesium, etc.

The sulphates of sodium and of magnesium, the tartrates of sodium and potassium and the phosphate of sodium are given in solution, the last often in milk. Unless under special conditions the salts ought not to be in greater concentration than 5–10 per cent. Magnesia and magnesium carbonate are administered in powder, sweetened if necessary. The effervescent preparations are always to be taken in solution in about a tumbler of water; in some instances in which this was not understood, severe distention of the stomach with alarming symptoms have arisen from the carbonic acid being freed in the stomach. The effervescent preparations ought to be kept dry, and the solution of magnesium citrate has to be kept tightly corked.

Very often the natural mineral waters are used instead of the pharmacopœial preparations, the best known purgatives among these being the Hunyadi-Janos water and Carlsbad water, which contain the sulphates of sodium and magnesium. "Carlsbad salts" are obtained by the evaporation of the waters, but are very often artificial imitations. Many other springs have the same effects, and a widespread belief exists that the natural waters are "more efficient" or "less depressant" or have some mystical virtues that are not shared in by the artificial salts, but this belief does not seem to have any real basis, and is probably a survival of the old religious belief in the healing properties of springs.

In the natural waters the purgative salts are always accompanied by other less active ones, such as the chlorides of sodium, calcium, etc.

Agar-Agar may be mentioned here as, although it has no chemical relation to the saline cathartics, its action presents certain analogies and it has been used

for similar purposes. It is obtained from various East Indian sea-weeds, and consists mainly of gelose, a carbohydrate which is indigestible and unabsorbable and retains water in the alimentary canal in the same way as the saline cathartics. It thus increases the bulk of the contents of the bowel and causes their evacuation in constipation. *Agar* (U. S. P.), 10 G. (2½ drs.) is given suspended in water or in food in chronic constipation. It is almost tasteless.

Other inert and unabsorbable fluids may be used to increase the intestinal contents and thus promote peristalsis; thus the liquid petrolate or paraffin (p. 52) has been used in constipation with success; but sometimes it passes through the canal without carrying with it the ordinary contents, and in some patients it tends to escape from the anus in small quantities without causing an evacuation of the bowel. About ½–3 oz. may be given each day in one dose or in divided doses before meals.

The same effect may be obtained by the use of bulky and indigestible foods such as green vegetables or coarse meal.

Therapeutic Uses.—The saline cathartics are very largely used to relieve constipation. Habitual constipation seems to be caused by insufficient peristalsis, and the slow passage of the contents through the intestines allows of a more complete absorption than usual, this in turn rendering the fæces hard and dry and difficult to move onward. The saline cathartics increase the fluidity of the intestinal contents, and thus facilitate their expulsion, and this is probably the only effect they have when taken in small quantities, and especially in dilute solution as in the natural mineral waters. In larger quantities, however, more water is retained in the bowel, and the weight and distention cause peristalsis, while in sufficient quantity they draw fluid from the blood and cause profuse watery discharges. When a very complete evacuation is desired, the saline cathartics may be given along with some of the vegetable purgatives. Such mixtures are the official Black Draught (see Senna) and the compound powder of Jalap. The saline cathartics act much more rapidly than the vegetable purgatives, and a common method of combining their effects is to give the latter in the evening and the saline the following morning; in the same way a mercurial purge, such as calomel, given in the evening, may be followed by a Seidlitz powder in the morning.

The chronic constipation due to sedentary habits is much benefited by the saline cathartics, more especially by dilute solutions taken before breakfast. The sulphates and tartrates are harsh and unpleasant to the taste, and the natural waters are often preferred, or one of the effervescent preparations may be used in those cases.

The sulphates and tartrates are more frequently used where a single large dose has to be prescribed in order to empty the bowel, but here also the Seidlitz powder may be advised instead, as being more agreeable to the taste. These cathartics were at one time used in fever, partly from a theory that they reduced the temperature; they are certainly less liable to cause pain and griping than the vegetable purgatives, and thus tend to disturb the patient less.

The sodium phosphate is often prescribed for children, either as a powder to be given in jelly, or in solution in milk or other food, which completely hides its taste.

The saline cathartics are used to lessen intestinal putrefaction, and are sometimes very efficient, though they do not act through any antiseptic power, but simply by removing the putrefying mass. The phosphate of sodium has been especially recommended in some forms of diarrhœa in children.

The saline cathartics are administered to remove accumulations of fluid in the body arising from cardiac or renal insufficiency, or from an old effusion. For this purpose the sulphate of magnesium is used in a large dose, dissolved in about its own weight of water; if purgation does not follow in 1–3 hours, an enema may be necessary, or the saline may be given along with a vegetable purgative. This form of treatment was very popular at one time, but is liable to weaken and depress the patient, and is specially contra-indicated, therefore, in asthenic conditions. Other methods of removing accumulations of fluid are by the use of diuretics (see caffeine), diaphoretics (see pilocarpine), or cardiac remedies (digitalis).

An analogous effect may play a role in reducing intracerebral pressure. Cushing has found that hypertonic sodium chloride solution given by the mouth relieves high pressure of the cerebrospinal fluid, presumably by withdrawing the fluid of the blood by diuresis; it seems likely that the cathartics given in adequate doses would be more efficacious by withdrawing fluid by the bowel.

As diuretics the saline cathartics are inferior to other salts, such as the acetates or nitrates. Large quantities of dilute solutions of the purgative salts are of value in the treatment of some forms of obesity, the mineral waters being generally prescribed for this purpose, or the patient being sent to drink them at their source.

Magnesia and magnesium carbonate are less liable to purge than the soluble salts, and are specially indicated in hyperacidity of the stomach or in acid putrefaction in the bowel. They cause less disturbance of the digestion than the carbonates of the alkalies because of their insolubility, and at the same time have the advantage of acting as mild purgatives, while the insoluble alkaline lime preparations, tend to induce constipation. The magnesia preparations may be used also in diarrhœa as antacids, as they have no irritant action on the bowel. A combination of antacid, carminative, saline and vegetable aperient is found in Gregory's powder, which contains magnesia, rhubarb, and ginger (p. 97). Freshly prepared magnesia is recommended in arsenic poisoning to form an insoluble precipitate in the stomach, and in poisoning with acids it is also of value when it can be obtained readily. In both cases it is to be given in large quantities.

The phosphate of sodium has been given in various bone diseases, as in osteomalacia and rickets, this treatment being founded on the belief that the softening of the bones is due to the lack of phosphates in the food, but there is no reason to suppose that this idea is correct, and the treatment is not attended with success. It has also been recommended in the uric acid diathesis. The phosphates have been supposed to be of benefit in nervous diseases, on the theory that these were due to the insufficiency of phosphorus in the brain, and

glycero-phosphates have been introduced for the same reason, but there is never any deficiency in the supply of phosphates in the food, and in practice no benefit is seen from the use of these salts.

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XI. VEGETABLE ASTRINGENTS—TANNIC ACID SERIES.

A large number of vegetable substances owe their action to their containing tannin substances, while in many other preparations the effect of more important constituents is modified by the presence of these widely distributed bodies. Tannic acid proper is a feebly acid substance derived from the oak gall, and is a compound of gallic acid, $C_7H_6O_5$, into which it is easily decomposed. Gallic acid is formed from a large number of other bodies which closely resemble tannic acid in their general features, but are by no means identical with it. Their constitution is altogether unknown, but they possess a number of reactions in common and are generally classed together as the tannic acid substances. Some of them contain a sugar, and tannin or tannic acid is therefore sometimes said to be a glucoside. These bodies precipitate albumins, gelatin, alkaloids and some glucosides, and the salts of the heavy metals; the salts of iron form a bluish-black or greenish-black precipitate.

Action.—The pharmacological effects of these bodies are due to their precipitating albumins and other proteins, and this reaction may therefore be described before their action in the body. If tannic acid solution is added to a neutral or weakly acid solution of albumin, peptone, or gelatin, a white precipitate falls, which is entirely insoluble in water, but is soluble in excess of albumin or gelatin, in stronger acid, and in alkaline solutions. This protein tannate exposed to the action of the gastric juice, undergoes digestion and is dissolved in the same way as an ordinary coagulated protein such as fibrin. During the process the tannic acid is set free from its combination and if it reaches a position in which the reaction is nearly neutral, it can again precipitate proteins. Strong alkali prevents the precipitation and the so-called tannates of the alkalies are thus devoid of this action.

Tannic acid applied to animal tissue, as in the tanning of leather, causes a precipitation of the proteins, and the tissue becomes harder

and tougher and tends to shrink together; at the same time it has less tendency to undergo putrefactive changes and does not lose its flexibility, as it would in drying. Applied to a living mucous membrane, which is neither strongly acid nor alkaline, a dilute tannin solution precipitates a fine pellicle of mucus and protein, which protects the cells beneath and lessens their sensitiveness to external stimuli. A stronger solution may cause some precipitation in the cells themselves and thus injure them and cause irritation.

Tannic acid solutions have a harsh, bitter, "astringent" taste, and produce in the mouth a feeling of constriction, dryness and roughness, along with a sense of stiffness in the movements of the tongue, and some loss of taste. These effects are due to the coagulation of the superficial layers of protein which substitutes for the ordinary smooth surface a firmer, less even one over which the tongue can no longer move easily. The feeling of constriction may, perhaps, be caused by an actual shrinking of the superficial layers of the epithelium, or may be due merely to the impaired movements and sensation.

The astringent feeling is continued in the throat as the solution is swallowed, and occasionally some irritation or even nausea and vomiting are provoked by it, but as a general rule, no such effects are observed. The stools are rendered harder and firmer by the administration of tannic acid, and constipation is often produced by it. In excess, tannic acid sometimes causes irritation of the intestine and diarrhœa, but beyond these symptoms of local irritation of the stomach and bowel, no effects arise from even enormous quantities of the drug.

In the resting stomach, tannic acid combines with any protein substance with which it may come in contact and precipitates it, but as digestion progresses and the reaction becomes more strongly acid, this combination is broken up. In the intestine the reaction becoming again less acid, tannic acid causes the same superficial precipitation as in the mouth, and the pellicle of precipitated protein acts as a protective to the mucous membrane. The contents thus have less effect in starting the peristaltic reflex and the movements are retarded, so that there is longer time for the absorption of the fluid part of the contents, although this proceeds more slowly under tannic acid than normally (Gebhardt). The secretion of mucus by the intestinal epithelium is lessened (Frey), and this may also retard the passage of the contents, which therefore become drier and harder. Hesse states that the constipating action is exercised chiefly in the large bowel when tannalbin is given, but this may not hold for the ordinary forms of tannin. Yeasts and microbes are precipitated by tannin, and this may tend to lessen the fermentation in the bowel in some cases, although some preparations of tannic acid which have been examined in regard to this point have been found to have little or no effect on intestinal putrefaction.

The local application of tannic acid causes a diminution of the secretions of glands, as has been demonstrated by Schütz. This is due to its effects upon the protoplasm of the secreting cells, which probably undergo the initial stages of coagulation.

It is often stated that tannic acid constricts the vessels of any part to which it is applied, but this is not supported by accurate observations. In acting as a protective to mucous surfaces, it may reduce congestion, but there is no reason to suppose that it acts more directly on the vessel walls, or, in fact, that it ever reaches them in an active form. In the same way it may indirectly lessen the inflammatory exudation from the vessels and the leucocytosis.

When tannic acid comes in contact with blood in a test-tube it precipitates the proteins, and when it is injected intravenously, the precipitate formed leads to the formation of emboli.

The fate of tannic acid in the body has given rise to some discussion. When it is taken internally, a small proportion is sometimes eliminated by the bowel unchanged, but very often none is to be found in the stools; traces are apparently absorbed and excreted in the urine in both man and animals, although some investigators have failed to detect these. But much the greater part of the tannic acid is decomposed in the intestine into gallic acid, some of which often passes out in the stools, some in the urine. Only about 1 per cent. of the tannic acid swallowed reappears in the excretions, either as tannic or gallic acid; the rest apparently undergoes complete oxidation, for no further trace of it can be found. After tannic acid is administered, some tannic or gallic salt is present in the blood, for iron salts give a darker color to it, but it is impossible to state whether this is tannin or a gallate, although in all probability it is the latter. According to Harnack, the gallic acid in the urine sometimes forms pyrogallol on standing, but this poisonous substance is not formed from tannic acid in the intestine or tissues.

Tannic acid then does not exist in the tissues as such, but only in the form of traces of the gallate or tannate of sodium, which are so small as to be devoid of astringent properties. The effects of tannic acid are therefore limited to the point of application, and it exercises no action after absorption. The alkaline tannates are generally believed to be entirely devoid of astringent effects, but the tannic acid is freed to some extent by such feeble acids as carbonic acid, so that the astringent action is present in the intestine.

Gallic acid given by the mouth is absorbed and is excreted by the kidneys to some extent. Much of it disappears in the tissues, however, apparently by oxidation. Gallic acid has no astringent properties and is quite useless in therapeutics.

The numerous preparations of the pharmacopœias which owe their activity to their containing tannic acid, differ from the pure drug in that the acid is only slowly dissolved out from the colloid mass, and therefore acts less on the stomach and affects a greater length of intestine.

Preparations.

Acidum Tannicum (U. S. P., B. P.), tannic acid, gallotannic acid or digallic acid ($HC_{14}H_5O_9$), an organic acid obtained from nut-gall. 0.5 G. (8 grs.).

Glyceritum Acidi Tannici (U. S. P.), Glycerinum Acidi Tannici (B. P.).

Unguentum Acidi Tannici (U. S. P.), 20 per cent.

Trochisci Acidi Tannici (U. S. P.), 0.06 G. (1 gr.); (B. P.), ½ gr. in each.

Gambir (U. S. P.), an extract prepared from the wood of Ourouparia Gambir, 1 G. (15 grs.).

Tinctura Gambir Composita (U. S. P.), (flavored with cinnamon), 4 mils (1 fl. dr.).

Gambir has been substituted for the Catechu of former editions of the U. S. P.

Catechu (B. P.), an extract of the leaves and young shoots of Uncaria Gambier, 5–15 grs. (0.3–1 G.).

Tinctura Catechu, ½–1 fl. dr. (2–4 c.c.).

Trochiscus Catechu, each containing 0.06 G. (1 gr.) of catechu.

Krameriæ Radix (B. P.), Rhatany, the root of Krameria triandra, Krameria ixina and Krameria argentea.

Extractum Krameriæ (B. P.), 0.3–1 G. (5–15 grs.).

Kino (U. S. P., B. P.), the inspissated juice of Pterocarpus Marsupium, 0.5 G. (8 grs.); B. P., 5–20 grs.

Tinctura Kino (U. S. P., B. P.), 4 mils (1 fl. dr.); B. P., ½–1 fl. dr.

Pulvis Kino Compositus (B. P.), contains 5 per cent. of opium, 5–20 grs. (0.3–1 G.).

Other astringent drugs of this series, which offer no advantages over those already given are Witchhazel (*Hamamelis*), the leaves and bark of Hamamelis Virginiana; Logwood (*Hæmatoxylon*), the wood of Hæmatoxylon campechianum; Eucalyptus gum (*Kino Eucalypti*), obtained from several species of Eucalyptus; Nut-gall (*Galla*) an excrescence on one of the oaks caused by the punctures and ova of an insect, Cynips Gallæ tinctoria. These are still contained in the pharmacopœias, but promise to follow a large number of similar bodies which have been discarded.

Several new preparations of tannic acid have been introduced into therapeutics of late years, chiefly for use as intestinal astringents. Tannic acid itself is liable to produce irritation of the stomach, and to be decomposed or absorbed to a large extent before it reaches the large intestine, and although the cruder preparations are less liable to these changes, even they are by no means devoid of disagreeable features. Meyer, therefore, introduced *tannigen*, or diacetyltannin, which is insoluble in water but appears to be dissolved in the intestine and there to act like tannic acid. *Tannoform* and *tannopin* are similar compounds. *Tannalbin* is a combination of tannic acid and albumen, dried at such a temperature as to prevent the action of the gastric juice upon it, but capable of being broken up by the more powerful pancreatic fluid. It is entirely insoluble and is not astringent until digested in the bowel, so that it has no irritant action on the stomach and is tasteless. *Tannocol* is a combination of tannic acid and gelatin, resembling tannalbin in most respects. The dose of these artificial compounds is 0.5–2 G. (10–30 grs.) in powder.

Several combinations of gallic acid have been introduced of late years as astringents, but they are merely inert protective powders. There is every evidence that such powders can protect wounded surfaces (see p. 53) or mucous membranes by covering them mechanically, and talc has been employed in diarrhœa. Charcoal in fine powder has also been prescribed partly for mechanical protection of the intestinal surface, partly for its power of absorbing gases, irritant substances and even bacteria.

Therapeutic Uses.—The preparations of tannic acid ought to be used for their local effects exclusively. They are applied externally in cases of excessive secretion, as in local sweating or weeping ulcers, and occasionally to harden the skin. For this purpose tannic acid may be used in solution in water, or in the form of the glycerite or ointment, or some other fluid preparation may be preferred. A similar use is made of the metallic astringents, lead, zinc, and alum salts. Tannic acid is used as a mouth wash in cases of swollen gums, or relaxed throat, and may here be prescribed in a flavored solution or in the

form of lozenges, of which the pharmacopœia offers a choice. In certain forms of diarrhœa the astringent action of tannic acid is of considerable value, and occasionally when such drugs as cod-liver oil cause diarrhœa, tannic acid prevents this action without hindering their general effects. The pure drug is seldom used in these cases, as it is liable to derange the stomach and to form compounds with the albumins before it reaches the bowel, and catechu, krameria or kino is accordingly prescribed, either in the form of pills or in fluid preparations; a useful preparation is the compound kino powder, which combines the astringent action of tannin with the specific action of opium on the intestine (compare the similar preparations of lead and opium). Tannic acid stops hemorrhage by precipitating the proteins, when it comes into immediate contact with the bleeding point, but it is not of so much value for this purpose as some of the metallic astringents. When the bleeding point can be reached directly, the pure acid is used, but for hemorrhage of the intestine or stomach one of the extracts is preferred. Large enemata containing tannic acid have been advised in cholera, dysentery, and similar conditions.

In cases of poisoning with metals and alkaloids, tannic acid is often used to cause their precipitation in the stomach, but the tannate formed must be removed at once, as it is gradually dissolved in the digestive fluids. The administration of tannic acid is therefore only a temporary expedient to allow of active measures being taken to empty the stomach.

Some individuals are peculiarly susceptible to the action of tannic acid, which induces local irritation and inflammation wherever it is applied in these cases.

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XII. BILE.

The bile is very seldom used in therapeutics at the present day, although it was formerly credited with great healing virtues. It has a bitter taste, and may have some effect like the vegetable bitters, but has no advantage over these, and is not likely to be used to promote

the appetite now, although it was formerly used a a stomachic. The bile is found to precipitate the peptones in test-tube experiments, but does not appear to retard digestion in the stomach materially, judging from experiments carried out in a case of gastric fistula. In the intestine it is generally believed to act as an antiseptic, chiefly because the stools have a strong putrefactive odor in cases of retention of bile. Limbourg has also shown that the addition of bile to protein solutions delays their decomposition, while there is some evidence that it promotes pancreatic digestion. It has some purgative action, as is shown by the obstinate constipation which often occurs when it is prevented from reaching the intestine; according to Stadelmann, the bile acids irritate the mucous membrance of the large bowel and thus induce purgation. Some of the drastic purgatives fail to act in the absence of bile, apparently because they are not dissolved by the other secretions (p. 92). Bile increases the activity of the fat-splitting ferment of the pancreas and thus augments the absorption of fats, but it is doubtful whether bile given by the mouth has this action. Most of the bile given by the mouth is absorbed in the intestine and carried to the liver, which excretes it again, while a small quantity of the bile acids escapes in the urine. In the liver it increases the secretion of both the fluid and the solids of the bile; in fact, the bile is the only reliable cholagogue known. The constituent which acts on the secretory liver cells seems to be the bile acids, and their increase is greater than can be accounted for merely by the excretion of that administered, so that it would seem that they exercise some specific stimulant action on the secretory cells. The bile pigment is also augumented when bile acids are absorbed, owing to the destruction of the red cells of the blood, as the liberated hæmoglobin is carried to the liver and there formed into bile pigment.

Bile given by the mouth does not cause any symptoms except those from the intestine and liver. When it is injected into the blood, however, it depresses the central nervous system and the heart muscle from its direct action on these organs, and dissolves the red cells of the blood in the same way as the saponins, which it resembles in reducing the surface tension. Muscles and nerves suspended in a solution of bile salts rapidly lose their irritability, and some unicellular organisms are killed and dissolved by them. The poisonous constituent of the bile seems to be the salts of the bile acids, but several authors have stated that the pigment is also active.

Fraser discovered that the bile acts to some extent as an antidote to the snake venoms through its containing cholesterin, which retards the absorption of the venom; it is much more efficient when it is mixed with the poison before its application, than when it is injected after the bite. Others have found that the bile of animals dying of an infectious disease (rinderpest) possesses some curative properties in other animals suffering from the same malady, this being explained by the excretion of the antitoxin in the bile.

Bile has been used as a purgative, and it has been particularly recommended in the form of an enema. It does not seem to be reliable, however, and presents no advantages over soaps and similar substances.

As a cholagogue it is without rival, but no condition is known in which an increase of the bile secretion is indicated, for though it has been proposed to expel gall-stones by raising the pressure in the gall-ducts by cholagogues, it is found that when the pressure is only slightly increased, the secretion is arrested. It is inconceivable that the small rise in pressure could force out an impacted gall-stone.

Bile might be used to aid the absorption of fats, particularly when it is deficient in the bowel; in a case of biliary fistula Joslin found that much less fat and nitrogenous food escaped in the stools when the patient was treated with bile pills, than when no treatment was adopted.

Preparations.

Fel Bovis (U. S. P.), ox gall, the fresh bile of the ox.

Extractum Fellis Bovis (U. S. P.), *Fel Bovinum Purificatum* (B. P.), is formed from the fresh bile by the addition of alcohol, filtration and evaporation.

Bile is always prescribed in the form of pills made from the purified preparation. 0.1 G. (1½ grs.); B. P., 5–15 grs.

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XIII. ANTHELMINTICS.

Anthelmintics are drugs which are used to kill or remove intestinal worms. They are often divided into vermicides and vermifuges, according as they kill or merely cause the expulsion of the worm, but this is determined largely by the quantity which comes in contact with the parasite and the rapidity with which the bowel is evacuated.

In order to possess any value as an anthelmintic, a drug must, of course, act more strongly on the parasite than on the host, and this more intense effect may be attained either by a specific action on the parasite, or by the drug failing to be absorbed from the alimentary canal. As a matter of fact, the anthelmintics have not been shown to possess any such specific action, but seem to injure most forms of living matter; this has been demonstrated more particularly for muscle tissue. Their use is thus rendered possible only by their slow absorption which permits of their acting on the parasite in greater concentration than on any of the tisues of the host.

Before the administration of an anthelmintic, the bowel ought to be emptied of its contents as far as possible by a light, easily digested diet and a laxative, and a brisk purge ought to follow some hours later, in order to remove the dead or stupefied worm. The anthelmintic is often prescribed along with a purge.

A number of drugs belonging to other groups are used occasionally as anthelmintics. Thus several of the volatile oils—tansy, turpentine—have some reputation; and chloroform is also administered occasionally by the mouth for its action on the parasites, but, like the volatile oils, is apt to produce gastric and intestinal irritation. The less easily absorbed antiseptics, such as naphthol, have been used with good results. Large enemata of salt solutions, or of infusion of quassia, are thrown into the rectum when the worms infest the large intestines. Many other drugs enjoy some popular reputation as "worm-cures," but have proved inferior to the recognized remedies.

Male fern, cusso and pomegranate are those most largely used for tapeworm; thymol has been used with great success in hookworm (uncinariasis) while santonin is the chief anthelmintic in infection with round worm.

1. Male Fern (Aspidium, Filix-mas).

A number of ferns contain bodies which present considerable resemblance to each other from a chemical as well as from a pharmacological point of view, and which may therefore be classed together, at any rate until further information is available regarding them. The best known of these is the male fern (Aspidium, Filix-mas).

The active constituent of this remedy was supposed to be *Filicic Acid* by Poulsson, but Boehm has found other neutral and acid bodies present, *Aspidinin*, *Flavaspidic Acid*, *Albaspidin*, and *Aspidinol*—and Kraft has added *Filmaron* and *Flavaspidinin*. These bodies are all derivatives of phloroglucin and butyric acid, and it is still uncertain whether the effects of male fern are to be attributed to any one of them or whether all of them may not share in the action. Jacquet holds that the chief therapeutic factor is the filmaron, but that the others also have some effect.[1]

Action.—The extract or oleoresin of male fern, which is the only one of these plants used in regular medicine, as a general rule passes through the bowel without causing any symptoms whatever. The quantity of active substance dissolved, while sufficient to destroy the parasite, is too small to produce any effects on the host, and escapes with the other contents of the bowel, or if absorbed does not cause any symptoms. In rare cases, however, where large quantities are administered, or where some unknown conditions favor the absorption and retention of an unusually large amount of the active constituents, grave and even fatal symptoms may supervene. These consist in vomiting and purging, with acute pain in the abdomen, muscular weakness, confusion and somnolence, with occasional twitching of the muscles, or slight convulsive movements, collapse, coma, and death. The stomach and intestine are found congested and swollen, and sometimes covered with small ecchymoses. In some cases icterus has been

[1] Nearly related bodies have been found in Aspidium athamanticum (Uncomocomo), which contains two forms of *Pannic Acid*, and in Aspidium spinulosum, while smaller quantities of acids occur in a large number of ferns. Several of these ferns enjoy a reputation as anthelmintics for tapeworm, and their virtues are generally considered due to these bodies

observed to follow the administration of male fern, probably from the duodenal catarrh, but possibly from destruction of the red blood cells the number of which has been found to be diminished in some instances (Georgiewsky). In other cases permanent or temporary blindness has resulted from neuritis and subsequent atrophy of the optic nerve.

In the rabbit, filicic acid produces very similar symptoms. The congestion of the stomach and intestine is evidently due to the local irritation produced by the poison, while the other symptoms point to changes induced in the central nervous system. The spinal cord is stimulated, for the reflex excitability is increased, but the higher parts of the central nervous system seem to be depressed, and the paralysis of the respiratory centre is the cause of death, although the heart is also weakened by filicic acid. Inflammation of the kidney is said by some authors to occur, and in some cases Poulsson found evidence of glycuronic acid in the urine.

In the frog, a mixture of depression and stimulation of the central nervous system is produced by filicic acid, along with distinct diminution in the strength of the skeletal muscles and the heart.

Aspidin (from Aspidium spinulosum) causes dyspnœa and paralysis of the spontaneous and respiratory movements in frogs; fibrillary twitching of the muscles sets in after some time and is succeeded by convulsive movements or tonic spasms, which indicate an increased activity of the reflexes of the spinal cord. The heart is depressed and eventually paralyzed, and the peripheral muscles are also weakened. The muscular tissue of the invertebrates is more powerfully affected by the constituents of male fern, and Straub attributes its action on the tapeworm to its paralyzing muscle. Mammals do not seem to be affected by aspidin injected hypodermically or administered by the mouth, but when it is introduced directly into the bloodvessels, it proves fatal by paralyzing the respiratory centre. Aspidinin induces very similar symptoms in the frog, while the other constituents are less active.

The blindness which has been observed in some cases of male fern poisoning has also been produced in dogs; it occurs chiefly in young, weakly, and anæmic individuals.

Pannic acid differs from filicic chiefly in its acting more strongly on muscle and less on the central nervous system of the frog.

Preparations.

Aspidium (U. S. P.), **Filix-mas** (B. P.), Male fern, the rhizome of Dryopteris Filix-mas and of Dryopteris marginalis.

Oleoresina Aspidii (U. S. P.), 2 G. (30 grs.).

Extractum Filicis Liquidum (B. P.) contains 20 per cent. of active principles, 45–90 mins. (3–6 c.c.).

Therapeutic Uses.—Male fern is used exclusively in the treatment of tapeworm and of Anchylostomum duodenale. Previous to its administration the bowel ought to be emptied, as far as possible, by a moderately light diet for one or two days and, where necessary, by a purgative. The oleoresin, or liquid extract, is then to be administered in the form of pills or enclosed in a capsule or suspended in mucilage, and another purgative is required some 6–12 hours later. In case the parasite fails to be dislodged, several days ought to be allowed to elapse before a second dose is given. Poulsson recommends that oily substances be avoided during the "cure," as they dissolve the active bodies, and thus promote their absorption. Other authorities dispute

this view and some consider that oils in dissolving the active principles render them more poisonous to the parasites, but it is certainly suggestive that in many cases of poisoning with male fern castor oil had been given along with it or soon after. Marked anæmia, general debility and chronic alcoholism seem to predispose to male-fern poisoning, and the drug is accordingly to be used with care in these conditions.

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2. Cusso.

Cusso, or Kousso, contains a neutral body, *Kosotoxin,* which is soluble in alcohol and in alkaline fluids, but is insoluble in water; it is a compound of phloroglucin and butyric acid like the constituents of male fern, which it resembles somewhat in its pharmacological action.

Cusso has a bitter, somewhat astrigent taste, and sometimes causes nausea and vomiting and some looseness of the bowels. In rare cases prostration and collapse, with irregularity of the pulse, are said to have occurred from its use.

In the frog, kosotoxin paralyzes the nerve ends like curara, and has a specific action on the striped muscular tissue, which it weakens and eventually paralyzes. The heart muscle undergoes similar changes. In mammals the muscular action is well developed, but is accompanied by some stimulation of the medullary centres, indicated by rapid, dyspnœic breathing, salivation and vomiting. The stools are often fluid, and the urine is increased in amount. When it is injected directly into the circulation, some convulsive movements are often observed, and the heart is weakened and paralyzed. Kosotoxin seems to be a general protoplasm poison, as is indicated by its action on muscles and by its retarding the growth of yeast.

Cusso (B. P.), (Kousso or Brayera), the pistillate flowers of Brayera anthelmintica, is generally given by suspending 15 G. ($\frac{1}{2}$ oz.) of the powdered flowers in water. Kosotoxin has not yet been prescribed for therapeutic purposes. The usual preliminary treatment ought to be instituted, but no purge is required after Cusso as a general rule. It is used exclusively as an anthelmintic in cases of tapeworm.

Kamala is a reddish-brown powder which consists of the minute glands and hairs obtained from the surface of the fruits of Mallotus Philippensis. It contains a neutral crystalline substance *Rottlerin,* which, like the active principles of male fern and Cusso, is a derivative of phloroglucin. Kamala is used in cases of tapeworm in doses of 2–8 G. (30 grs.–$\frac{1}{4}$ oz.) suspended in water. It acts as an intestinal irritant, causing purging and, more rarely, nausea and vomiting. No purge is necessary, therefore, after the powder. An alcoholic tincture of kamala has been found quite as efficient as the powder. Rottlerin resembles the active constituents of several other anthelmintics in possessing a strong

action on muscle tissue whether striated or unstriated, in which it induces rigor; it also has some depressant effect on the central nervous system, particularly on the motor areas.

Areca Nut, the seeds of the palm Areca Catechu, is used in veterinary medicine as a remedy in tapeworm. It contains a fluid alkaloid, arecoline ($C_8H_{13}NO_2$), which resembles pilocarpine in action. In addition, it contains several inactive alkaloids and tannic acid.

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3. Pelletierine.

The bark of the pomegranate contains a very large amount of tannic acid (20–25 per cent.), along with several alkaloids, of which *Pelletierine*, or *Punicine*, and *Isopunicine* alone are active in ordinary doses. All the pomegranate alkaloids are closely related chemically to each other and to tropine (see atropine). None of them can be classed among the more active poisons as far as man and the higher animals are concerned.

In man, large doses cause heaviness, confusion, giddiness, and very marked weakness of the limbs. The consciousness is but little affected but the sight is often dim and uncertain, and in one case complete blindness persisted for several days. Occasionally nausea and discomfort in the abdomen are complained of, and more rarely vomiting, tremors, and cramps of the leg muscles are produced; the gastric symptoms are perhaps due to the large quantity of tannic acid in the drug rather than to the alkaloids.

In the frog and in most mammals, pelletierine causes a distinct increase in reflex irritability of the spinal cord and medulla oblongata, along with some depression of the higher divisions of the central nervous system. Very large doses weaken or paralyze the conductivity of the nerve plates in the frog, like curara. The heart muscle is also acted on and its pulsations are slowed in the frog, although they may be temporarily augmented in force.

Pelletierine and isopunicine have a specific action on tapeworms, for Schroeder found that a solution of one part in 10,000 was sufficient to kill them in ten minutes, while a stronger solution had practically no effect upon other intestinal worms.

Pelletierinæ Tannas (U. S. P., B. P.), a mixture in varying proportions of the tannates of four alkaloids (punicine, isopunicine, methylpunicine and pseudopunicine), obtained from pomegranate bark. Dose, 0.25 G. (4 grs.); B. P. 2–8 grs.

Therapeutic Uses.—Pomegranate is used exclusively as an anthelmintic, and the crude bark has now been displaced almost entirely by the tannate. The preliminary treatment is the same as that given under male fern, and a purge ought to be given one to two hours after the vermicide.

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4. Thymol.

Thymol ($C_{10}H_{14}O$) is a crystalline substance obtained from the volatile oil of Thyme and other plants, and chemically is a homologue of phenol. It is very insoluble in water and when taken in solid form appears to be absorbed from the alimentary tract with difficulty.

In man, thymol has caused depression, nausea, vomiting, headache and confusion with roaring sounds in the ears and alarming weakness of the heart resulting in giddiness and collapse. Its irritant action on the mucous membrane may cause burning sensations in the stomach and vomiting.

In poisoning in animals it induces a condition of weakness and apathy which passes into collapse and death, generally without any convulsions. Fatty degeneration of the liver, congestion or even consolidation of the lungs, and irritation of the intestine are found *postmortem*. Half or more of the thymol ingested is destroyed in the tissues; the rest is excreted in the urine in combination with sulphuric and glycuronic acid; it is said to have caused renal irritation in some cases, as shown by the appearance of albumin and even of blood in the urine.

Thymol (U. S. P., B. P.) ($C_6H_3C_3H_7CH_3OH$) occurs in common thyme and other plants, and forms large colorless crystals which have the odor of thyme and are very insoluble in water. The dose as an anthelmintic is given as 1 G. (15 grs.) per day, but this is often exceeded.

Thymol is used widely as an anthelmintic in hook-worm disease (anchylostomiasis or uncinariasis); it is given in capsules or emulsions in doses of 30 grains repeated in two hours and followed in six or eight hours by a brisk saline purge. The bowel should be emptied as far as possible by light diet and an aperient before the treatment is begun. Thymol in $\frac{1}{10}$ per cent. solution is also used as an antiseptic (see p. 142).

Some other volatile oil bodies, such as carbon tetrachloride (CCl_4), have been used as anthelmintics, and the *Oil of Chenopodium* has recently been advocated in hook-worm disease. It is said to require less careful preparation of the patient than thymol treatment and to cause nausea less often. Some symptoms of intoxication have been recorded in a few cases.

Oleum Chenopodii (U. S. P.), American wormseed, is given in doses of 10 mins. in capsules or on sugar and is followed by a purge in two hours. The treatment is repeated for three days.

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5. Santonin.

Santonin ($C_{15}H_{18}O_3$) is an anhydride of santonic acid, a derivative of naphthalene. It occurs in Artemisia pauciflora along with a nearly related body (artemisin) and a volatile oil (cineol). Santonin is very insoluble in water, but is dissolved by alkalies, with which it forms santonates.

Action.—Owing to its insolubility in water, santonin has only a slightly bitter taste in the mouth. It is partially dissolved in the stomach and passes into the bowel where it effects the removal of some forms of intestinal worms. Under special conditions part of the santonin may be absorbed in the bowel, however, and general poisoning results without the parasites being affected. A certain amount of absorption occurs in every case, as is shown by the disorders of color vision and by the yellow coloration of the urine. At first objects appear of a bluish color to the patient, but this aberration is of comparatively short duration and may in fact pass unnoticed. It is followed by a much longer period of "yellow sight" or xanthopsia, during which objects that are brightly illuminated seem to have a yellow tinge, blue seems green, and violet is indistinct, although in dimmer lights the violet may still predominate. In severe poisoning the appreciation of the darker colors becomes very imperfect, and violet and even blue may fail to be distinguished from black. In general the violet end of the spectrum is shortened, while the yellow impresses the retina more vividly than normally. In some cases the senses of taste and smell, and more rarely the hearing are also deranged. These symptoms all pass off in the course of a few hours, a second stage of "violet sight" occasionally intervening before complete recovery.

The symptoms produced by the absorption of large quantities of santonin are so uniform in man and the other mammals that it is sufficient to enumerate those observed in experiments on the dog. The first distinct effects are generally twitching of the muscles of the head, frequently beginning on one side. These are followed by rolling of the eyes, grinding of the teeth, flexion and extension of the neck and rotation of the head from side to side, later by regular epileptiform convulsions in which the animal is first thrown into opisthotonos and then into clonic spasms of the limbs and trunk. These are interrupted by intervals of repose during which a curious momentary contraction of all the muscles of the body is often noticed. During the convulsive seizures the respiration is irregular and insufficient, and in fatal cases it fails to return after the convulsion passes off, and the animal dies of asphyxia. In man, some confusion, nausea and vomiting occasionally occur after quantities which are too small to produce convulsions, and in several cases aphasia has been observed. In frogs, convulsions are produced by santonin as in mammals, but they are preceded by a prolonged stage of depression, which is entirely absent in the higher animals.

These symptoms manifestly point to changes in the central nervous

system. The xanthopsia is generally referred to a specific action on the retina, though some hold that the central apparatus of vision in the brain is the seat of the action. The condition has been ascribed to a preliminary stimulation and subsequent depression of the sense organs for the perception of the violet and eventually of the blue rays of the spectrum, or more precisely to some obstruction to the regeneration of the substance in the retina which normally appreciates violet rays (Filehne). The clonic nature of the convulsions at once points to an affection of the brain rather than of the cord, and the epileptiform convulsions are generally regarded as arising from stimulation of the cortex in the higher animals and man, though the basal cerebral ganglia may also be involved; the sudden contractions observed in the intervals of repose are ascribed to stimulation of the gray matter in the region of the pons.

Santonin undergoes some oxidation in the tissues and is excreted in the fæces and urine in several forms, two of which have been examined by Jaffe and found to be oxysantonins. The urine and sometimes the fæces have a deep yellow color, which changes to red or purple when alkalies are added. A similar reaction is obtained from the urine after the administration of rhubarb or senna.

Santonin is universally used as a remedy for the round worm, Ascaris lumbricoides, and most clinicians believe that it has a specific poisonous action on these animals, and that its undoubted effects are due to its killing them. In experiments on the entozoa outside the body, santonin was not found to be very toxic to them, but this appears to have been due to its not having been completely dissolved in the absence of bile, for Sollmann found it fatal to earthworms in low dilution when bile salts were added. Santonin, like other anthelmintics, often causes active movements in the worms before killing them and they are often expelled in this condition, although this movement ceases very soon afterward from the exposure to cold.

Preparations.

Santoninum (U. S. P., B. P.), $C_{15}H_{18}O_3$, a neutral principle derived from Artemisia pauciflora, is colorless when freshly prepared, but assumes a yellow color when exposed to the light. This does not seem to impair its activity materially, but it is preferable to avoid it by keeping santonin in amber-colored vials. Dose, 0.06 G. (1 gr.); B. P., 1–3 grs.

Trochiscus Santonini (B. P.), each containing 1 gr.

Therapeutic Uses.—Santonin is used almost exclusively to remove Ascaris lumbricoides from the intestine. It is much less effective against tapeworm or other intestinal parasites. It may be prescribed as a powder, or lozenge, or in solution in oil.

The bowel ought to be emptied by suitable diet and a laxative before the santonin is administered, and a sharp purge ought to be given two to four hours afterward in order to bring away the entozoa.

Santonin has been advised in some retinal diseases, but the results have generally been unsatisfactory.

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Spigelia.

Another remedy used in cases of round worm is pink root, Spigelia maritima, the active principle of which is unknown, although an alkaloid, *spigeline*, is said to occur in it. Occasional cases of poisoning have been observed, especially in children, the symptoms consisting in flushing and dryness of the skin, often with some œdematous swelling of the face, delirium and sopor followed by dimness of sight or temporary blindness. In frogs spigelia appears to depress the brain and spinal cord, and the heart beats more slowly and weakly, while in rabbits the most prominent symptoms arise from the breathing, which becomes slow and labored and finally ceases in a convulsive attack. In the dog and cat its injection is followed by vomiting, great weakness and incoördination of the movements, restlessness, rapid dyspnœic respiration and finally by stupor, coma and death from failure of the respiratory centre.

Spigelia (U. S. P.), the rhizome and roots of Spigelia marilandica.

Fluidextractum Spigeliæ (U. S. P.), 5 mils (1 fl. dr.).

The fluidextract is used to remove round worms, which it seems to affect in very much the same way as santonin. It ought to be preceded and followed by a purge.

XIV. ANTISEPTICS AND DISINFECTANTS.

Various balsams, tars and other aromatic bodies have long enjoyed a certain reputation in the treatment of wounds, but the whole course of surgery was changed about 1870 when Lister introduced the systematic application of antiseptics to wounded tissues. The general principle underlying this treatment was that infection arises from the invasion of the tissues by microörganisms and that it can be combated either by preventing them from reaching a wound or by retarding their growth on the injured surface by means of antiseptic drugs. The first of these which he introduced was carbolic acid, and this held its position unchallenged for several years, when it was discovered that many other substances were equally destructive to the microörganisms and were less poisonous to the invaded tissues. Of late years the tendency has been rather to prevent the infection of the tissues by careful manipulation (asepsis), but when this is impossible the use of antiseptics and disinfectants is still necessary, and even the newer aseptic surgery depends in part on the use of disinfectants to cleanse the skin and instruments

A disinfectant in the strict use of the term is a substance used to destroy microbes, while an antiseptic, while not actually killing the

germs, prevents their growth as long as it remains in contact with them. A disinfectant is accordingly only intended to act for a short time, for if the infected matter be once rendered sterile it can only become dangerous by being again contaminated. For example, a room requires only to be disinfected after a case of infectious disease. A wound, on the other hand, even though completely disinfected may become contaminated again very easily and an antiseptic may be required to prevent the further growth of microbes. Many substances are disinfectant in large quantities and antiseptic in more dilute solutions, but others are too weak to disinfect thoroughly though they retard the growth of pathogenic organisms, and still others may be employed to disinfect but are unsuitable for use as antiseptics, either because they are too poisonous to be applied for a sufficient time, or because they lose their activity on contact with living matter (*e. g.*, oxidising disinfectants).

A very large number of substances possess disinfectant properties, that is, are capable of destroying microbes when they can be applied in sufficient quantity. They have no specific action on the microbes, however, but act as general protoplasm poisons destroying living tissue of all kinds wherever they come in contact with it. On the other hand, drugs such as strychnine, which act on specialized parts of the vertebrate organism and have less effect on the less differentiated tissues, are equally harmless to the undifferentiated protoplasm of the microbes. It is of importance to note that the ordinary antiseptics do not act more strongly on microbes than on the tissues in which they are embedded or the phagocytes with which the organism is combating the infection. The destruction of the septic organisms in a wounded surface entails the destruction of the surrounding cells also. Thus disinfection can only be carried out in a part in which the superficial cells are not of vital importance and may be restored by new growth. It is therefore impossible to disinfect the tissues of the body as a whole, because a drug circulating in the blood in sufficient quantity to destroy the bacteria in the body would be equally detrimental to the organs in which they are embedded. Unless a drug has a specific affinity for the parasite,[1] much greater than that for the tissues of the host, it can only be used where the parasite can be overwhelmed by a massive dose, and this at the expense of the neighboring tissues. The problem is not insoluble, however, but requires the discovery of a reagent which shall differentiate between the protoplasm of bacteria and that of man, in the same way as chemical reagents differentiate between such bodies as potassium and sodium; the two forms of protoplasm of course differ from each other much less than the metals. Quite recently some progress has been made in this quest, for Browning and his associates state that certain basic substances, notably *Flavine* or *Acriflavine* (diaminomethyl-acridinium chloride), act more strongly as disinfectants in

[1] A drug which has a specific affinity for a parasite as compared to the organs of the host is said to be parasitotropic, while the affinity for the organs in general is called its organotropic tendency.

serum than in water and kill bacteria in a concentration 400 times lower than that required to interfere seriously with phagocytosis. Similarly, Morgenroth has shown that some alkaloidal substances of the quinine series possess a selective action on the pneumococcus, which they are able to destroy in the mouse without injury to the host. This use of basic substance seems to be promising, for there is more probability of their being freed in the body fluids and thus penetrating more readily into the organisms than is possible for acidic substances. Recent work also tends to show that some drugs are more potent against certain bacteria, others against other species, so that an imperfect specificity seems to be present. Thus far, however, the promising results of test-tube experiments have not been confirmed when put to the test in infections in living animals. There is, therefore, hope that the limitations set to the use of disinfectants in this chapter may have to be modified, but further experience is necessary. In the meantime they hold for all the disinfectants and antiseptics which are in general use.

The antiseptics and disinfectants act upon most forms of living matter, and in many instances their effects are obviously due to their possessing powers of oxidizing or of coagulating proteins. In other instances their destructive action is not so open to explanation. And the amount of destruction induced varies with the degree to which the poison penetrates the tissues to which it is applied. For example, mercuric chloride diffuses deeply into tissues brought in contact with it and causes wide destruction, while the oxidizing disinfectants lose their efficacy on meeting proteins and thus affect only the most superficial cells. If microbes were confined to the surface, the latter would be sufficient for their destruction, but in order to disinfect a wound it is necessary to penetrate more deeply and thus efficient disinfection implies a certain amount of destruction of the tissues in which the microbes are harbored. This local destruction of cells and nervous structures induces pain and irritation and all efficient disinfectants are irritants. Their action as irritants arises from the same qualities as their disinfectant power, namely, from their general toxicity to living matter, and it is impossible to dissociate the one from the other and to produce non-irritant effective disinfectants.

When a surface has been poisoned by means of disinfectants, it heals less quickly, and this has led to the more sparing use of antiseptics and to the development of the aseptic method, in which organisms are excluded instead of being admitted and then destroyed.

In addition to their local effect, many of the antiseptic and disinfectant drugs have a further poisonous action when they are absorbed and circulate in the blood, and this has led to a further limitation of their use. This general action does not necessarily arise from the qualities which render them antiseptic, and may be avoided by care in the choice of the drug and in its use.

The action of different drugs upon the microörganisms varies in nature in the same way as the action on other living cells. Some apparently penetrate into the interior in virtue of their solubility in lipoids,

and this penetration is facilitated by anything which decreases their solubility in the surrounding medium. Others accumulate on the surface of the organisms by adsorption, so that the microbe is surrounded by a dense layer of disinfectant. Yet others appear to enter into true chemical combination with the constituents of the parasites. Some of the antiseptics (*e. g.*, carbolic acid) enter the cell by simple diffusion and do not accumulate in its interior in greater concentration than in the solution surrounding it. Others (*e. g.*, corrosive sublimate) tend to accumulate in the cell and on its surface by adsorption, and thus are withdrawn from the solution if a sufficient number of microbes are present.

The efficiency of any disinfectant naturally depends on the concentration in which it comes in contact with the microbes and the time during which it remains in contact with them. Thus a solution of mercuric chloride of the strength of 1 in 3000 is much more efficient than one of 1 in 10,000, and after exposure to a solution for five minutes far fewer microbes escape than after exposure for two minutes. Another factor is the temperature at which the microbes are exposed to the disinfectant, for it is found that when the latter is kept at about 30° C. far fewer bacteria escape than when ordinary room temperature prevails. Different species of microbes vary in their resistance, and different cultures of the same microbe and even different individuals of the same culture exhibit marked variations in susceptibility. The effect also often varies inversely with the number of microbes present, because each of these withdraws a certain amount of the disinfectant and thus reduces the general concentration of the solution. And other proteins have the same influence as the microbes themselves, for they offer the disinfectants the same surface for adsorption or combine with some of them in the same way as the proteins of the microbes. Thus a concentration which is sufficient to sterilize water infected with bacteria, may have little or no effect if applied to a suppurating wound, because the greater part of the disinfectant is taken up or otherwise rendered inactive by the proteins of the secretion, leaving only a low concentration to act on the microörganisms. Thus Bechhold has shown that many substances which are powerful disinfectants in ordinary fluids, lose their activity in protein solutions, owing to their forming combinations with the proteins, so that though they are not dangerous to the host, they are comparatively innocuous to the microbes in the tissues; in fact they act on proteins and not specifically on microbes; when the proteins are present in small amount, as in an emulsion of bacteria in water, these disinfectants are active enough, but when the bacteria are distributed among the proteins in an infected wound, the amount of the disinfectant that falls to the share of the bacterial proteins is too small to be effective. For example, a disinfectant which prevented the growth of diphtheria germs in broth when added in the proportion of one in half a million, had no action on the germs in the tissues when it was present in the proportion of one in five thousand, because it combined with the tissue proteins in preference to those of the bacilli.

This again indicates the limitation of disinfectant therapeutics,

which cannot be overcome as long as the drugs have no elective affinity for the invading organisms but act equally strongly on the tissues of the higher animals.

If a poison is to penetrate into the interior of an organism in quantity, it must be as soluble in the protoplasm as in the fluid in which it is applied, for it is obvious that it will not leave a medium in which it is readily soluble for one in which it is dissolved with difficulty. Accordingly, it is found that fats and oils in which the members of the aromatic series are very soluble are not suitable as media for their application, for the poisons remain in the oily menstruum and fail to penetrate the microbes in which they are less soluble. On the other hand, the addition of inorganic salts to an aqueous solution of carbolic acid often increases its antiseptic power, because the poison becomes less soluble in the water and shows a greater tendency to escape from it into the interior of the microbes.

There is reason to believe that solutions containing several disinfectants are more strongly antiseptic than those containing an equal percentage of the individual pure bodies; for example, a mixture of carbolic acid and mercuric perchloride, is more efficient than a much stronger solution of either alone. This appears to be due to a change in the solubility of the disinfectant, at any rate in some cases.

Disinfectants and antiseptics are used for a large variety of purposes and it may be well to consider the principles which underlie their uses before discussing the special features of each drug.

1. **In Surgery**, Lister advised that not only infected wounds should be treated with disinfectants but that infection of any wound should be guarded against by the application of antiseptics which would retard the growth of microbes. It is now recognized, however, that a clean wound requires no antiseptics and heals more quickly if they are avoided. And disinfection in surgery is now applied only to tissues already the seat of infection, and to objects which may come in contact with a clean wound. Among the latter, those which offer the greatest difficulty are the skin of the patient and of the operator, and a large number of drugs have been employed to disinfect these and render them harmless. Among the disinfectants more commonly used to disinfect the skin or to destroy the organisms in a wound already infected, are the carbolic acid group, mercuric chloride, the oxidizing disinfectant group, and iodine, of which the last has recently been the most popular. The disinfectant must be applied in solution or suspension in water, and should induce as little irritation as is compatible with its fulfilling its purpose. This is of special importance in dealing with the delicate, sensitive mucous membranes such as the eye, which cannot be subjected to such treatment as would be necessary in other parts of the body. A danger which is smaller now than formerly is from the absorption of the disinfectant giving rise to general poisoning. This arose as a general rule not from the drug applied during the operation, but from its too lavish use in the subsequent dressings. But cases of poisoning are still met from the use of powerful disinfectants to wash out large abscesses, the uterus, or other organs.

Instruments, ligatures, etc., are generally disinfected by heat, but are often kept in dilute solutions of carbolic acid or other disinfectant until required.

The relative disinfecting power of the drugs used in surgery has been investigated repeatedly but no satisfactory ratio can be given as yet, because it is impossible to imitate the conditions in a septic wound closely enough in experimental determinations. And estimations of the relative power in destroying organisms in water or in gelatin cultures depend upon a variety of conditions, such as the number of organisms and the completeness with which the disinfectant is removed before test growths are made. It is generally held that among the disinfectants used in surgery mercuric perchloride is superior to the carbolic acid group, and that both of these penetrate more efficiently than the oxidizing disinfectants.

2. **In the Treatment of Skin Diseases**, a number of disinfectants have been employed, and where the area of infection is small it may be permissible to use the more powerful ones if necessary. But in widespread disease the dangers of local irritation and of absorption preclude all except the least noxious, and it remains a question how far these act in retarding the growth of an infecting organism, and how far their effects may be due to their causing slight irritation and improved nutrition. Some dermatologists hold the view that these mild skin remedies owe much of their value to their reducing properties. Among these remedies are chrysarobin, pyrogallol, naphthol, and the tar series.

3. **To Disinfect the Intestine.**—Septic processes may occur either in the contents of the intestine or in its walls, the former affecting the general organism only by the production of poisonous or irritant substances which may be absorbed, while in the latter the tissues of the wall themselves become the seat of active disease. It is possible that an admixture of a disinfectant with the contents of the bowel may retard their putrefaction, and this method of treatment has been largely employed. When the evidence of its efficacy is examined, the results prove to be disappointing; the amount of double sulphates or of indol in the urine is said to be diminished, and the number of microbes in the fæces to be reduced under the use of these intestinal antiseptics, but this is no longer regarded as unequivocal evidence that the disintegration of the food by microbes is retarded; and in addition these changes in the urine and the fæces have not been confirmed by many observers. There is some rather unconvincing clinical evidence of improvement under this treatment, but it is now recognised to be more in accord with general aseptic procedure to remove the putrefying contents by means of a purgative, than to attempt to render them sterile in the bowel by means of disinfectants.

When the bowel wall itself is the seat of infection the use of antiseptics and disinfectants is still less supported by the results. And it seems very unlikely that a drug powerful enough to destroy the microbes harbored in the mucous membrane will leave the latter uninjured. In typhoid fever, in which this treatment has been carefully followed,

the number of typhoid bacilli in the stools has not diminished to any noticeable extent, and the use of these drugs does not relieve the symptoms or shorten the duration of the disease.

Any drug used for the disinfection of the intestine must not be irritant, nor very poisonous. It must not be too soluble, since otherwise it may be absorbed from the upper part of the bowel, and on the other hand it must be soluble to some extent, or it cannot mix very intimately with the contents of the intestine. Carbolic acid is scarcely fitted for this purpose, for it irritates the stomach and is also rapidly absorbed. Some of the cresols have been recommended of late years, and the naphthol preparations have also enjoyed some reputation. Salol and its congeners have the advantage of being almost completely insoluble and harmless in the stomach and of being dissolved and rendered active by the intestinal juices. The purgatives are the most efficacious treatment and, among these, the mercurials are largely used.

4. **To Destroy Pathogenic Germs in the Tissues After Absorption.**—It is now recognized to be hopeless to attempt to find a single body which will destroy all forms of bacteria in the tissues, while leaving the host uninjured, but there is still reason to believe that in the future specific antiseptics may be found for at least some of the constitutional diseases. Such a specific action is seen in the effects of quinine on the organism of malaria, of salicylates in rheumatic fever, of mercury, arsenic and antimony in various protozoal infections, and of emetine in amœbic dysentery,[1] all of these apparently acting more strongly on the cause of the disease than on the tissues of the patient. While it may be hoped that the antiseptic treatment of internal maladies has not reached its final limit, it is futile to attempt to disinfect the tissues generally with ordinary agents, which are much too poisonous.

5. **In the Treatment of Septic Genito-urinary Diseases.**—The treatment of general infections in the tissues with non-specific disinfectants is hopeless for the reasons given above. On the other hand, good results are obtained in infection of the genito-urinary tract through which many of the antiseptics are eliminated from the body. In the course of their elimination they are concentrated; thus a quantity of disinfectant which is inactive when distributed through the protein-rich tissues of the body, may very well be efficacious when it is dissolved in the comparatively small quantity of the urine, and especially since here it finds no protein to combine with except that of the tract through which it passes. On the other hand, in their passage through the body the antiseptics are generally formed into combinations which are less irritant and also less poisonous to the microörganisms. There is, however, no question that the continual washing of the genito-urinary tract with the antiseptics in the course of their excretion reduces the

[1] It is to be remarked that in malaria, syphilis, dysentery, and trypanosomiasis, in which specifics have been obtained, the disease is due to invasion by protozoa, while most of the infections of which the cause is known, arise from bacteria, and these appear to be much less susceptible to the action of chemical agents.

number of the organisms in the urine and relieves septic conditions. The drugs used for this purpose must not be too irritant to the mucous membranes of the alimentary tract, and must be easily absorbed and not dangerously poisonous. Many of the aromatic series, such as salicylates, have been employed, and some of the volatile oils. An important advance has recently been made in urotropin, which is harmless and inactive itself but frees formaldehyde in acid urine. In addition to this method of treatment, antiseptics and disinfectants may be applied by injection into the urethra and bladder by the ordinary surgical procedure.

6. **In the Treatment of Pulmonary Infections.**—Traces of some of the more volatile antiseptics are eliminated in the breath, and this has suggested their internal use to destroy microbes in the lungs, especially the tubercle bacillus. It may be stated, however, that careful observers are united in the belief that this form of medication is entirely useless. The case of the lungs differs entirely from that of the kidney, for in the former there is no concentration of the disinfectant in the organ, but it is excreted in even greater dilution than that in which it circulates in the general tissues; the surface of lungs has been estimated at about 70 square meters, and it is impossible to conceive that small quantities of antiseptic spread over this surface can affect bacteria harbored on it. Again chloroform is a fairly efficient disinfectant which is absorbed and excreted by the pulmonary endothelium, yet no improvement occurs in lung disease from the inhalation of chloroform during an operation; on the contrary the endothelium is more likely to suffer from the remedy than the microbes. Antiseptic remedies have also been inhaled in vapor or spray, and have been injected into the trachea or even into the lung directly, but as far as the tubercle bacillus is concerned, they have had no result in the hands of more careful observers. In fact this bacillus appears to be peculiarly refractory to most chemical disinfectants, which can be administered by the mouth. In cases of gangrene of the lung, fœtid bronchitis, etc., the inhalations relieve the patient to some extent and certainly lessen the offensive odor.

7. **In Infections of Other Secretions and Organs,** the use of antiseptics has not proved successful. In the bile, thymol and urotropin have been found after administration by the mouth, and the latter has been shown to occur in the cerebrospinal fluid and in many other excretions, but it is to be noted that urotropin is in itself inactive and is disinfectant only through its liberation of formaldehyde, which does not take place except in the urine.

8. **To Disinfect Rooms, Furniture, Clothing, Excrementa,** the strongest and cheapest drugs which are available are employed. It is quite futile to attempt to carry out such disinfection unless with concentrations which would be immediately fatal to all higher organisms. For rooms and furniture, formaldehyde or sulphur dioxide are best adapted as they are volatile and penetrate fairly, but the latter bleaches all dyed material. Clothes are best disinfected by heat, or formaldehyde solution may be employed. Excrement may be disinfected by chlorine

or lime; crude carbolic acid and tar are less certain, and the oxidizing disinfectants are expensive when used in quantity.

9. **To Disinfect Drinking-water.**—Water may be freed from infectious organisms by heat or filtration, but when these are not available, chemical disinfection may be necessary, as for example in military expeditions. The disinfectant must not be present in such quantities as to render the water poisonous, or even disagreeable to the taste. Fortunately, the organisms are not protected by the presence of colloids and are therefore destroyed by very small quantities of disinfectants. The most convenient is chlorine which may be carried in the form of hypochlorite or may be formed from sea-water by electrolysis. Hydrogen peroxide has also been employed.

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Many antiseptics and disinfectants are used for a variety of purposes and might be classed under several of these headings. The following arrangement is therefore an arbitrary one, and merely points to the use for which the drug has been considered most adapted.

I. Surgical Antiseptics and Disinfectants.

1. Carbolic Acid.

Carbolic acid, or phenol, the first of the modern antiseptics to be introduced, acts like the rest of the simpler benzol compounds as a **General Protoplasm Poison**, although in the vertebrates it affects the central nervous system more powerfully than the other tissues.

Its poisonous effects are well seen when it is applied to unicellular organisms, such as the *protozoa*. Even dilute solutions cause immediate arrest of all movements; the organism assumes a spherical shape and loses its transparency, and, unless the solution be very attenuated, dies in the course of a few minutes. *Plant cells* are acted on in the same way, and the individual cells of more highly organized animals, such as the *ciliated epithelium* of the air passages and the *spermatozoa*, are killed at once when brought in contact with carbolic acid. There is

some evidence, however, that very dilute solutions of carbolic acid, as of other antiseptics, tend to increase the activity of protoplasm, for while solutions of phenol, such as are used as surgical antiseptics, are immediately fatal to the yeast plant, very dilute solutions increase its activity. The effect of carbolic acid on protoplasm has, however, been studied chiefly in the *bacteria*. Its antiseptic power, while always considerable, is found to vary greatly with the species of microbe. Thus, while it is fairly poisonous to the ordinary pyogenic organisms, it has to be present in very concentrated form to destroy the more resistant spores of anthrax, and like other antiseptics, is much less poisonous to the microbes than to the protozoa and other simple forms of life. The development and reproduction of many microörganisms has been found to be much delayed, or altogether prevented, as long as they remained in a solution of one part of carbolic acid in 400–600 parts of water, but in order to kill them very much more concentrated solutions (5 per cent.) were required, and Koch found that the spores of the anthrax bacilli were destroyed by 5 per cent. carbolic solution only after they had remained in it for two days.

It seems to vary considerably in its action on the *unorganized ferments;* thus it is said not to retard appreciably the fermentations produced by emulsin, diastase and myrosin, even when present in the solution up to 5 per cent., while pepsin, ptyalin and the rennet ferment are weakened by somewhat smaller quantities.

Carbolic acid precipitates **Proteins** in solution and also in the cells. It does not seem to enter into any firm combination with them, for it can be washed out of the precipitate with comparative ease. It results from this that carbolic acid penetrates more thoroughly than the metallic antiseptics, which are rendered insoluble by the protein they meet, and whose action therefore tends to remain confined to the surface.

This coagulation of the proteins occurs whenever carbolic acid is brought in contact with the tissues. On the **Skin** a white, opaque scar is formed by concentrated phenol, which becomes red and shining afterward and then falls off in a few days, leaving a light brown stain which may remain for several weeks. Even a 5 per cent. solution applied to the fingers produces tingling and warmth, which is often followed by opacity and shrinking of the epidermis and a sense of numbness. This numbness may amount to almost complete anæsthesia if more concentrated solutions are applied, no pain being felt even when the skin is cut through. When applied for some time and prevented from evaporating, carbolic acid may cause extensive dry gangrene of the part, from its penetrating through the surface layer and reaching the deeper tissues. Applied to a **Wound** in 5 per cent. solution, phenol induces pain and irritation followed by local anæsthesia, and a white pellicle of coagulated proteins is formed. It causes irritation and necrosis of the **Mucous Membranes**, and if applied in sufficient quantity may lead to sloughing and acute inflammation. This local effect may prove fatal from shock and collapse when large quantities of the undiluted

acid are swallowed, the effects resembling exactly those produced by other corrosive substances. Carbolic acid is rapidly absorbed from the stomach and bowel, but after some time the absorption is much slowed owing to local changes in the vessels of the intestine.

General Action.—In *man* delirium and excitement have been observed in some cases, but convulsions are comparatively rarely seen. When large quantities are taken, immediate unconsciousness may result and death follow within a few minutes. How far this is due to the local corrosion, and how far the direct action on the central nervous system is involved, cannot be determined. In more gradual poisoning, depression and weakness, headache, nausea and vomiting are followed by giddiness, noises in the ears, pallor and collapse, with irregular pulse and respiration, and cold perspiration; fainting and unconsciousness then lead to failure of the breathing and death. Fatal poisoning may arise from swallowing a concentrated or a dilute solution, or from absorption from wounds and abscesses. It has also occurred in man from absorption through the unbroken skin.

The autopsy sometimes gives no special indications of the cause of death, save the local corrosion of the alimentary canal. Inflammation and necrosis of the intestine is said to have been observed in some cases in which the poison was absorbed from skin wounds, and fatty degeneration is sometimes induced in the liver and the renal epithelium, but is not constant.

In the *frog* carbolic acid first causes depression and loss of the spontaneous movements, and later fibrillary twitching in the muscles, augmented reflex excitability and finally tonic convulsions. These may last for some time and then complete paralysis of the central nervous system supervenes, while the heart and the peripheral nerves and muscles remain active. A dilute solution of carbolic acid applied directly to the exposed spinal cord paralyzes the sensory elements immediately, while leaving unaffected the motor fibres and the cells of the anterior horn (Baglioni).

In *mammals* very similar symptoms are produced, save that there is often no noticeable preliminary stage of depression. Some weakness and lethargy may be present, however, and is followed by marked muscular tremor, which resembles the shivering produced by cold. At intervals this is interrupted by sudden twitches in different muscles, and later by clonic convulsions. The respiration and the pulse are at first accelerated, but afterward are slow, irregular, and weak. The movements become feeble and appear at longer intervals, the respiration is shallow and irregular, and the animal passes into a condition of collapse, in which, however, the sensibility to pain is often preserved. Eventually death occurs from asphyxia. After very large doses the collapse may be immediate, no convulsions being observed, the heart and respiration often ceasing simultaneously. In most cases salivation is a marked symptom, and the temperature often falls far below the normal.

Central Nervous System.—The convulsions in the frog arise from increased irritability of the spinal cord, especially of the anterior horn cells, for they are not arrested by section of the medulla oblongata. In mammals the sudden contractions of isolated muscles appear due to a similar action on the spinal cord, but the clonic convulsions and the persistent tremors are probably of cerebral origin, and Berkholz found the cerebral cortex abnormally irritable after carbolic acid. The rarity of convulsions in man has not been satisfactorily explained. In some cases the course of the intoxication is too short, the large amount of poison swallowed inducing immediate collapse, while in others their absence may be due to the debility of the patient from disease; but in a considerable number of cases of poisoning in which neither of these conditions was present, no convulsions were observed. The primary stimulation of the central nervous system in animals is followed by depression and paralysis if large doses are administered.

The acceleration of the **Respiration** and of the **Heart** seen in mammals has been supposed to be an indirect result of the increased muscular movement and convulsions, but this seems to be incorrect, for the heart is found to be accelerated before the convulsive movements and tremor appear, and the frog's heart is accelerated in cases where no movements whatever occur. It would seem probable that the acceleration of the heart is due to direct action on the muscle or on the regulating nerves. The subsequent slowing is undoubtedly due to muscular action.

The acceleration of the respiration precedes the increased movement also, and would therefore seem to be due to action on the medullary centre, which is first stimulated and later paralyzed. The vasomotor centre is depressed by the injection of carbolic acid into the blood, and this, together with the weakness and slowness of the heart, causes a fall in the blood-pressure and collapse.

The peripheral **Nerves and Muscles** do not seem to be affected in general poisoning in mammals, although in the frog their irritability and the capacity for work of the muscle may be somewhat reduced.

On the direct application of solutions of carbolic acid to the nerves or muscles, these are killed at once, like other forms of living matter; even dilute solutions paralyze the nerve fibrils and terminals and thus induce local anæsthesia.

The increased **Secretion** of saliva, perspiration and tears which is seen in poisoning in mammals is probably of central origin, and may possibly be associated with the nausea and vomiting.

The fall in **Temperature** in carbolic acid poisoning seems, for the main part, to be due to the collapse, although it is impossible to state how far this may be aided by some alteration of the regulating function, such as is seen in the closely related group of the antipyretics.

Carbolic acid added to the defibrinated **Blood** leads to the slow formation of methæmoglobin, but this does not occur in the living animal. Occasionally some destruction of the red-blood cells is caused in animals through the injection of carbolic acid directly into the blood-vessels, and in one case of poisoning in man hæmoglobin was detected

in the urine, indicating that some of the red cells of the blood had been destroyed.

Excretion.—Some of the carbolic acid absorbed is oxidized to hydroquinone and pyrocatechin, and these and also the unaltered carbolic acid are excreted in the urine in combination with sulphuric and glycuronic acid. The hydroquinone and pyrocatechin tend to become further oxidized to colored substances and the urine therefore assumes a dark, dusky-green color which may change to brown or even black. This change may occur in the body, and the urine is very often passed of a greenish-brown color, but further oxidation takes place on exposure to the air, resulting in deeper coloration which commences at the surface of the fluid and gradually extends downward. The depth of the shade depends not on the amount of phenol sulphate in the urine, but on that of the dioxybenzols, and a darker urine is often observed, therefore, when the absorption has occurred from an open wound (in which the conditions are especially favorable to oxidation) than from much larger quantities absorbed from the alimentary canal.

The presence of glycuronates in the urine may lead to its reducing Fehling's solution, and thus give rise to the suspicion of glycosuria. On the other hand, the passage of these bodies through the kidney often causes some irritation and albuminuria. The double sulphates of the urine are, of course, much increased, and the inorganic sulphates are correspondingly diminished.

The **Chlorphenols**, in which chlorine is substituted for one or more of the hydrogen atoms of carbolic acid, are much more poisonous to microörganisms than the original substance, while their toxicity in mammals is not increased in the same ratio. A similar intensifying effect is seen in the chlorine substitution products of the narcotic series, *e. g.*, chloroform. The most poisonous of the monochlor-phenols is parachlorphenol. *Bromol* or tribromphenol has been used to a limited extent in therapeutics as a disinfectant and caustic.

Preparations.

Acidum Carbolicum (B. P.), Phenol (U. S. P.), carbolic acid or phenol (C_6H_5OH) forms colorless, deliquescent crystals when recently prepared, but often assumes a reddish tinge from oxidation. It has a characteristic odor and is intensely corrosive. It is soluble in about 15 parts of water, but becomes liquid when 10 parts of water are added to 90 of the crystals, forming the *Acidum Carbolicum Liquefactum* (B. P.), *Phenol Liquefactum* (U. S. P.). This must be carefully distinguished from the ordinary solution of carbolic acid, which contains only 2 to 5 per cent. of phenol, while the liquefied carbolic acid contains about 90 per cent.

Glyceritum Phenolis (U. S. P.), *Glycerinum Acidi Carbolici* (B. P.), 20 per cent. of carbolic acid in glycerin. 0.3 mils (5 mins.).

Carbolic acid is generally used in 2–5 per cent. solution. A crude, impure form may be employed to disinfect stools, latrines, etc. The glycerite may be used as a very weak caustic. Solutions of carbolic acid in oil have little or no antiseptic action, because they fail to penetrate into the microbes.

Therapeutic Uses.—Carbolic acid is used as an antiseptic in surgical operations in 2–5 per cent. solution in water. It now plays a much less important rôle in surgery than it did in the first days of antisepsis;

in fact in many clinics it is now employed only to preserve the instruments from infection. Its irritant action and the danger of absorption have also rendered it unpopular as a dressing or lotion after operations or injuries, where there is any large absorbent surface, or where irritation is liable to be injurious, as in most forms of skin disease.

It is still used as a disinfectant in septic wounds, though greater reliance is now placed on corrosive sublimate. Strong carbolic acid has been applied to disinfect wounds, its poisonous effects being avoided by immediately washing it off with alcohol.

Harrington has recently drawn attention to the danger of applying dilute solutions in bandages to injured fingers and hands; he found records of over a hundred cases in which this had led to gangrene, necessitating amputation.

Carbolic acid had a limited use as a caustic in the form of the liquefied preparation, and was less painful than most other caustics. It has also been employed in itching skin diseases, but is inferior to the cocaine series. Internally, it was at one time advocated as an intestinal disinfectant and as a remedy in constitutional diseases, but this has long been abandoned.

Poisoning.—In carbolic acid poisoning, when it has been taken by the mouth, the first treatment is the removal of the poison by the stomach tube and the thorough lavage of the stomach with water to which 10 per cent. of alcohol may be added; the alcohol dissolves the poison more readily than water and thus facilitates its removal, but has no other antidotal action, and should be removed from the stomach as completely as possible; when absorption has occurred from the skin or from a wound the dressing should be removed at once. The combination of phenol with sulphuric acid in the tissues forms a comparatively harmless body, and Baumann and Preusse therefore suggested the administration of sodium sulphate in large quantities. It is found, however, that this is of little or no use, because the phenol does not combine with sulphates as such in the body, but with organic sulphur compounds which are only in process of being oxidized to sulphuric acid. When coma and collapse set in, the patient is to be sustained by the application of warmth externally, and by the administration of such central nervous stimulants as caffeine or strychnine; artificial respiration may eventually be used, although there is little prospect of resuscitation if the intoxication has advanced so far. The corrosion induced by carbolic acid locally may be treated by washing the part with alcohol, which dissolves the acid readily.

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2. Cresols

Of late years the cresols or cresylic acids ($C_6H_4.CH_3.OH$) have been substituted for carbolic acid to a considerable extent in surgery. There are three isomeric cresols which all resemble carbolic acid closely in action, and which present only minor points of difference from each other. Metacresol is said to be less poisonous and less irritant than carbolic acid, while it is credited with a more powerful antiseptic action; orthocresol, on the other hand, is said to be more dangerous than carbolic acid, and paracresol to be the most poisonous of all. But the differences in toxicity between the cresols are too small to be of practical importance, and their germicidal action is approximately equal when they are used in suspension with soaps, as is usually the case.

Many cases of suicidal poisoning with cresol preparations have occurred and have presented symptoms similar to those of carbolic acid poisoning—collapse and exhaustion followed by coma and death; in some cases marked alterations have been found in the liver along with nephritis and haemolysis. Much of the cresol absorbed undergoes complete oxidation in the tissues, but about one-third of that ingested is excreted in the urine in combination with sulphuric and glycuronic acids.

The cresols are constituents of tars and other crude disinfectants. In pure form they are only slightly soluble in water, and it has been found necessary to form them into emulsions or suspensions for surgical use. A large number of these cresol preparations are available and differ chiefly in the way in which they are suspended in water (*creolin, solveol, solutol, lysol*). These preparations are not devoid of poisonous properties as is often stated; on the contrary they are little if at all less dangerous than carbolic acid. Their germicidal action has been overrated by some authorities and has been denied by others. On the whole they appear to be more powerfully antiseptic than carbolic acid when they are used in emulsion form; their insolubility in water facilitates their passage into the bacteria in which they are more soluble; and the emulsion form has a further advantage as the fluid coming in contact with the bacteria must always be saturated with the antiseptic. Cresol has been given as an intestinal disinfectant, but has not proved more useful than the other drugs used with this object.

The chlorcresols are said to be more strongly germicidal than the cresols themselves, while their toxicity is not increased in the same degree or may even be reduced; a suspension of chlorcresols has been introduced as an antiseptic, but has not yet been widely used.

Preparations.

Cresol (U. S. P., B. P.), a mixture of the three cresols, forms a colorless or straw-colored fluid with a phenol odor. Soluble in 60 parts of water. Dose, 0.05 mil (1 min.).; B. P. 1–3 mins.

Liquor Cresolis Compositus (U. S. P.), *Liquor Cresol Saponatus* (B. P.), Cresol 50 per cent. suspended in water by means of soap, is used diluted to about 2 per cent. as a surgical disinfectant.

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3. Other Aromatic Surgical Disinfectants.

Many other members of the benzene or aromatic series have enjoyed a more or less transient reputation as surgical disinfectants and antiseptics. Thus *Thymol* ($C_6H_3CH_3C_3H_7OH$), obtained from oil of thyme, was used to a limited extent as an antiseptic lotion in $\frac{1}{10}$ per cent. solution and also as a mouth wash and gargle, but in this strength it is only feebly active and it is too insoluble in water to form a really effective germicide. It is used as an anthelmintic chiefly (p. 124).

Salicylic acid ($C_6H_4OHCOOH$) and *sodium salicylate* ($C_6H_4OHCOONa$) were at one time used as antiseptic washes in surgery, and indeed promised to supplant carbolic acid for this purpose as they are less irritant and less poisonous. The acid is destructive to the pyogenic microorganisms suspended in water but has much less effect than carbolic acid when proteins are present, and its use has been abandoned in practice by most surgeons. The salicylates are used almost exclusively for their specific action in acute rheumatism.

Picric acid or trinitrophenol, $C_6H_2(NO_2)_3HO$, is used as an application to wounds or burns in the form of a saturated watery solution (1 per cent.) on lint. It has approximately the same disinfectant action as carbolic acid, but enters into a more stable combination with proteins and is thus slightly astringent. Larger quantities are irritant and in some cases have given rise to gastro-enteritis and nephritis; the skin and mucous membranes are stained yellow even when the picric acid is carried to them in the blood, and this coloration has sometimes been confused with jaundice. Violent convulsions occur sometimes, in other cases collapse. The urine is yellow or red and contains casts, but little albumin and no bile, the absence of the latter serving to distinguish the condition from jaundice; picric acid tends to destroy the red blood cells in animals but no marked fall in these has been observed in man. It is excreted as picramic acid ($C_6H_2OHNH_2(NO_2)_2$) in the urine.

The *sulphocarbolates* (or *paraphenolsulphonates*) of sodium and zinc are less poisonous than carbolic acid, as the sulphon group lessens the toxicity in the same way as the carboxyl one, but they are at the same time very much weaker in germicidal power. They have been used as external antiseptics, and the sulphocarbolate of sodium has been administered to arrest fermentation in the stomach with little success. *Aseptol* or *sozolic acid* is a 33 per cent. solution of ortho-phenol-sulphonic acid in water, but very often contains some of the para-acid. Of the three phenol-sulphonic acids, the ortho- is the most strongly antiseptic and the para- the least useful.

Sodii Phenolsulphonas (U. S. P.), or sodium para-phenol-sulphonate (C_6H_4-$OHSO_2ONa,2H_2O$), forms colorless, transparent prisms, without odor, and with a saline taste. Soluble in 5 parts of water. 0.25 G. (4 grs.).

The *oxynaphtoic acids* ($C_{10}H_6OH\,COOH$) possess antiseptic properties, which are said to be somewhat greater than those of carbolic and salicylic acids, but they are less soluble in water, while the sodium salt is less antiseptic. The acids are irritant and produce diarrhœa and symptoms similar to those of salicylic acid. They seem to be at least as poisonous as carbolic acid, and have been used as external antiseptics only to a very limited extent.

Turpentine oil and many of the other volatile oils enjoy a reputation as antiseptics and disinfectants, and have been applied to disinfect the skin before operations and for similar purposes.

Chloroform may also be mentioned as a disinfectant in use in the laboratory though it has never been adopted in surgical operations.

Alcohol is a disinfectant when used in 50–70 per cent. dilution, and has been used to clean and disinfect the skin and hands before operation.

4. Mercuric Perchloride.

Soon after the treatment of wounds with carbolic acid was established, its rival, corrosive sublimate, was introduced as a more powerful disinfectant. There is no question that the claim was justified and that corrosive sublimate in ordinary surgical practice has greater germicidal and antiseptic powers than carbolic acid. At the same time bacteria must be exposed for a longer time to its action before they are destroyed, and it has a more injurious effect on the tissues with which it comes in contact and is more poisonous when it is absorbed. A certain amount of mercury remains attached to the proteins of the microbes and restrains their reproduction even when it does not actually kill them; owing to this fact corrosive sublimate has been credited with greater disinfectant power than it merits, for it is found that on the complete removal of the mercury many of the inactive organisms recover; in practice its action is therefore partly disinfectant and partly antiseptic. The symptoms of mercuric poisoning and the general action will be discussed under the chapter on mercury (see Index).

Mercuric chloride solution (1 in 2000–4000) is used extensively in surgery to disinfect the hands, skin and wounds, but is very irritant to the unbroken skin even and must not be applied to more delicate tissues. It corrodes steel and this precludes its use to preserve instruments before use. It is sometimes employed in the form of a soap and to impregnate bandages, cottonwool, gauze, catgut, etc., but it renders all of these irritant and corrosive so that they should not be applied directly to wounded surfaces. It differs from the carbolic acid group in preserving its disinfectant powers in oils and fatty vehicles, in which it

is only slightly soluble and which it therefore leaves readily for the fluids of the microbes. It also differs from carbolic acid in the fact that the presence of sodium chloride reduces its disinfectant action because it lessens the amount of the free Hg ion. The disinfectant action of corrosive sublimate is much diminished by the presence of protein and it has less penetrating power than carbolic acid. It precipitates protein like other metallic salts and has a further specific toxic action on living tissue.

Various other mercurial salts have been suggested as disinfectants, for example the cyanide and periodide; other preparations are that with ethylenediamine (*sublamin*) or with sodium oxytoluate (*afridol*); but these have no advantages over the perchloride.

Toxitabellæ Hydrargyri Chloridi Corrosivi (U. S. P.) are used to form disinfectant solutions. Each tablet contains 0.5 G· of perchloride, and forms a solution of 1 in 2000, when added to a liter of water.

5. Other Metallic Disinfectants.

The salts of several other metals have been used as disinfectants and antiseptics. Silver nitrate is the most important of these and plays a large rôle in the treatment of infections of the mucous membranes, especially that of the eye. This disinfectant action is accompanied by intense irritation, but silver nitrate has very slight powers of penetration because it is rendered insoluble and therefore inactive by the chlorides of the tissues. Silver nitrate is used in solutions of 1 to 2 per cent. as a disinfectant in infectious ophthalmia, or in more dilute form (1 in 200–400) for more frequent application. It has also been used as an injection in gonorrhœal infection of the urethra in the strength of 1 in 500–2000 and in various other conditions. General poisoning is unknown from this use of silver, but its intensely caustic action and the limited extent to which it penetrates have prevented its wider employment. This irritant action of the nitrate has led to the introduction of various other salts and preparations (see Silver), which are less dissociated in solution and thus are less corrosive. But these lose their disinfectant power in the same ratio as they become less irritant, for the tissue destruction arises from the same factor as the disinfectant action, the free silver ion. The effects of silver after absorption will be discussed later (see Index).

6. Oxidizing Disinfectants.

Peroxide of Hydrogen.

Hydrogen peroxide or dioxide (H_2O_2) tends to break down into water and oxygen very rapidly in the presence of many substances, which in themselves may be either oxidizing or reducing. Among the bodies which induce this decomposition are the peroxidase ferments, which are found in all forms of living matter, and the peroxide of hydrogen is therefore decomposed when brought in contact with the

tissues; the oxygen thus liberated tends to oxidize its surroundings and its chief effects are therefore due to its oxidizing properties. It is generally met with in dilute solution in water, and in this form alone is used in medicine. Brought in contact with the skin, peroxide of hydrogen solution is decomposed, and numerous bubbles of oxygen are formed,[1] but this decomposition proceeds much more rapidly when it is applied to denuded surfaces or to mucous membranes. The oxygen is formed in such quantity that some irritation may follow, and thus dogs often vomit when it is administered in quantity by the mouth. When it is injected subcutaneously, a large amount of oxygen is formed in the subcutaneous tissues, but some of the peroxide escapes decomposition and is absorbed into the blood. Here the decomposition proceeds more violently, the red-blood cells having a strong catalytic action, and the oxygen set free may cause emboli and lead to sudden death. The formation of emboli is seen most frequently in the rabbit, but was in all probability the cause of death in one case of fatal poisoning in man, in which a solution of hydrogen peroxide had been used to wash out the pleural cavity.[2] Emboli are not formed in the dog on hypodermic injection, nor in either dogs or rabbits poisoned by the stomach—in the latter case probably because the liquid is more slowly absorbed and is almost entirely decomposed in the mucous membrane. Even in the blood and tissues the whole of the peroxide is not decomposed, for several observers have found traces of it excreted in the urine.

The catalysis of hydrogen peroxide occurs in the lower forms of life as well as in the higher. Thus germinating seeds, yeasts, infusoria and the microbes all free oxygen from the solution, and in fact, a rough estimate of the number of microbes in water may be formed from the amount of oxygen given off by it on the addition of the peroxide (Gottstein). This decomposition is fatal to most of these lower forms, from the nascent oxygen, and peroxide of hydrogen is therefore a powerful disinfectant in water, a 3 per cent. solution proving as strongly bactericidal as a 1 per mille solution of corrosive sublimate; but when the microbes are contained in a medium with much organic substance, as in wounds, the bactericidal action is very much reduced. This appears to be due to the too rapid decomposition of the peroxide, which escapes as bubbles of oxygen, comparatively little oxidation taking place. This may be exemplified by its action on the blood; when normal blood in a test-tube is treated with peroxide, it froths up and the oxygen escapes, leaving the blood unaltered. If, however, some hydrocyanic acid has been added to the blood some time previously so as to weaken the ferment, there is little or no effervescence and the hæmoglobin is changed to methæmoglobin by the peroxide remaining and freeing its oxygen more slowly. The peroxide therefore oxidizes most powerfully when it is slowly decomposed, while the rapid action of the ferments

[1] A concentrated solution is said to corrode the skin, leaving a white eschar.

[2] In several other instances hemiplegia has been observed, apparently from embolism of the cerebral arteries.

tends to dissipate the oxygen in the molecular form which has comparatively slight oxidizing and disinfectant powers.

In recent years, attention has been drawn to other bodies analogous to hydrogen peroxide, some of which possess powerful microbicidal properties. The peroxide is represented by the structural formula H—O—O—H and one of the hydrogens may be replaced by benzoyl or acetyl, forming C_6H_5CO—O—OH (benzo-peracid) or CH_3CO—OOH (aceto-peracid). These bodies give off oxygen more slowly than hydrogen peroxide and surpass it in germicidal power; in fact they are as powerful disinfectants as corrosive sublimate in favorable conditions. Unfortunately these peracids are too unstable for practical use; and the organic peroxides, such as diacetyl peroxide (CH_3CO—O—O—$COCH_3$), which form the peracids in water have not proved so useful clinically as the laboratory results seemed to promise.

Preparations.

Liquor Hydrogenii Dioxidi (U. S. P.), *Liquor Hydrogenii Peroxidi* (B. P.), solution of hydrogen dioxide or peroxide, contains about 3 per cent. by weight of the pure dioxide. Each volume of this solution is capable of setting free 10 volumes of oxygen when completely decomposed. Some acid is added to the peroxide solution in order to retard its decomposition, but it gradually changes when kept, so that only freshly prepared solutions are of full strength. The solution is colorless and odorless, but has an acid taste from the added acid, and the oxygen freed in the mouth gives a curious sensation and forms a froth.

Therapeutic Uses.—Hydrogen dioxide is used locally as a disinfectant solution in suppuration, diphtheria, and urethral infection. In pus cavities the oxygen is freed with great rapidity, and the pus-corpuscles are said to be disintegrated. The catalysis is due in part to these corpuscles, in part to the microbes, and the extent of the suppuration may be estimated from the amount of effervescence. Peroxide solutions differ from most other disinfectants in the short duration of the action, which passes off as soon as all the oxygen is liberated. In addition to its microbicidal action proper, this agent loosens and destroys masses of infected material by the mechanical effect of the liberation of the gas, and the wound or cavity is thus cleaned by it more perfectly than by washing with ordinary disinfectant solutions. Most surgeons believe that this mechanical action is of more importance than the direct germicidal effect. The solution has been recommended for use in ophthalmic practice, and for this purpose may be diluted one half.

Peroxide has been used to destroy the bacteria of drinking water and 10–15 c.c. of the pharmacopœial solution is found to reduce the bacteria in a liter of water more than 100 times; about twice as much is required to have the same effect in milk.

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Other Oxidizing Disinfectants.

Some older disinfectants also owe their powers to liberated oxygen, and among these that most largely employed is the *Permanganate of Potassium.*

When a solution of this salt comes in contact with organic matter, such as albumin, the permanganate at once parts with some of its oxygen, which attaches itself to the albumin. Permanganate is thus poisonous to protoplasm, not through the presence of the whole molecule, but in consequence of the oxidation of the proteins. As soon as the permanganate is reduced, it of course loses this action, so that the oxidizing effect is limited to the skin and the surface of the mucous membranes. Concentrated solutions irritate, and even corrode the skin, and induce gastro-enteritis when swallowed. Permanganate solutions are disinfectants of considerable power, owing to their oxidizing and thus destroying bacteria. They fail to penetrate deeply in an active form, and this renders them of less value than many other disinfectants, except in very superficial infection.

Potassii Permanganas (U. S. P., B. P.) ($KMnO_4$) forms slender crystals of a dark purple color and a sweetish, afterward disagreeable and astringent taste, soluble in sixteen parts of water, reduced by alcohol and other organic bodies. 0.06 G. (1 gr.).

Permanganate is used for its disinfectant and deodorant action, as an application to gangrenous ulcers, cancerous sores, diphtheria, and gonorrhœa. In dilute solution it may be used as a gargle and mouth wash ($\frac{1}{4}$ per cent.), to disinfect the hands (1 per cent.), which it stains brown, and for other similar purposes.

It has recently been recommended in poisoning with phosphorus, prussic acid, morphine and other alkaloids, on the theory that these poisons are oxidized by it in the stomach, and thus rendered harmless. For this purpose it is given in one-third per cent. solution. But permanganate also oxidizes the gastric mucous membrane, and it has not been shown that it attacks morphine in preference to the proteins; the treatment is certainly less reliable than the use of the stomach tube; permanganate has of course no action on morphine after absorption. In snakebite, permanganate has been used to wash the wound and also to inject around it; it has no effect upon the poison already absorbed.

Condy's Fluid is a strong solution of impure permanganate, which is of use to disinfect and deodorize urinals and fæces, but must be poured on them, and cannot be employed to disinfect rooms.

Some of the caustics owe part of their action to the oxygen liberated when they come in contact with organic matter. Thus *Chromic Acid* destroys tissue in part through its acidity but this is reinforced by its oxidizing powers

Other oxidizing bodies have been used as antiseptics and disinfectants. Thus *Calcium Peroxide* or *Gorit* has been recommended as a gastric and intestinal disinfectant for children in doses of 0.2–0.6 G. in milk. Zinc peroxide and magnesium perioxide have also been suggested, the former for external, the latter for internal use.

Similarly the *Persulphates* of potassium and sodium ($Na_2S_2O_8$), *persodine*, possess strong oxidizing properties from their liberating oxygen in contact with organic matter. They are only feebly poisonous but have not been extensively used as yet.

7. Boracic Acid and Borax.

Boracic or boric acid ($B(OH)_3$) is a very weak acid, and it is doubtful whether the hydrogen ions or acidity play any part in its action, or whether the whole is not to be referred to the rest of the molecule. The ordinary sodium compound, borax, $Na_2B_4O_7$, is stated by some authors to be equally active, but is alkaline in reaction, so that the exact relative importance of the two ions of boric acid cannot be determined. Boracic acid and its sodium salt have some antiseptic power, for in $2\frac{1}{2}$ per cent. solution almost all forms of bacilli stop growing; but they are not destroyed, even the delicate anthrax bacilli being found capable of further growth after exposure to a 4 per cent. solution for twenty-four hours. Boracic acid is therefore valueless as a disinfectant, but has been used as an antiseptic dressing; it has the advantage over many other antiseptics of inducing very little irritation and of being only slightly poisonous, but experience has shown that it cannot be used with impunity in very large quantities.

Action.—Boracic acid and borax are only feebly toxic, but large quantities taken by the mouth cause gastric and intestinal irritation, as is evidenced by vomiting and purging, and even smaller amounts are said to act as mild aperients in some cases. Not infrequently repeated small doses of boric acid have induced albuminuria, especially in persons predisposed to it. Moderate doses are without effect on the metabolism, but larger quantities (5–10 G. per day in dogs) increase the nitrogen excretion in the urine. A dose of 30–60 grs. of boric acid is found to increase the bulk of the fæces in man by retarding the absorption of the proteins and fats.[1] Both borax and boracic acid are rapidly absorbed by the bowel, and do not affect the intestinal putrefaction.

Boracic acid has been widely used as an antiseptic dressing, and a number of cases of serious poisoning have been recorded from its absorption. The symptoms arose in part from the alimentary canal, uneasiness in the abdomen, vomiting, diarrhœa, dryness of the throat and difficulty in swallowing; sleeplessness, great muscular weakness and depression, dimness of sight and headache were also complained of, and in severe cases collapse and death followed. The prolonged use of boracic acid, internally or externally, has repeatedly led to falling of the hair, eczema, and psoriasis. Papular eruptions and local

[1] The body weight often falls under borax treatment, and this has been attributed to augmented fat destruction by Rost and Rubner, who state that a corresponding increase in the carbonic acid elimination accompanies it.

œdemas and swelling of the skin appear, and a gray line on the gums, similar to that seen in lead poisoning, is stated to occur along with irritation of the mouth.

Boracic acid and borax are excreted in the urine, in which they appear within a few minutes after ingestion; over half the quantity taken is excreted within twelve hours, but afterwards the elimination proceeds more slowly, so that traces may be found in the urine for five days or more; the urine becomes alkaline after sufficient amounts of borax, as after any other alkaline preparation.

Acidum Boricum (U. S. P., B. P.), Boric or Boracic Acid (H_3BO_3), colorless crystals, with a faintly bitter taste, soluble to about 4 per cent. in water, more so in alcohol and glycerin. 0.5 G. (8 grs.); B. P., 5–15 grs.

Glyceritum Boroglycerini (U. S. P.), *Glycerinum Acidi Borici* (B. P.). Boroglycerin is a compound formed by heating boric acid in glycerin, and the official glyceritum or glycerinum contains this dissolved in glycerin, about 30 parts of boric acid being used to form 100 parts.

Unguentum Acidi Borici (B. P., U. S. P.), 10 per cent.

Sodii Boras (U. S. P.), *Borax Purificatus* (B. P.), Borax ($Na_2B_4O_7+10H_2O$) forms colorless crystals with a sweetish alkaline taste. It is soluble in water (25 parts) to which it gives an alkaline reaction. 0.75 G. (12 grs.); B. P., 5–15 grs.

Glycerinum Boracis (B. P.) (1 in 6).

Boracic acid has been used as a surgical antiseptic in solution (4 per cent.), ointment, or lint, and the solution of the acid or of borax is also used as a wash in aphthæ and other forms of irritation of the mouth. Boracic acid solution has been given internally in dilute watery solution as a genito-urinary disinfectant, has also been injected into the bladder, and is frequently used in ophthalmic surgery, as being less irritant to the eye than the more powerful antiseptics. Boracic acid and borax are sometimes added to milk or other food as preservatives, and it has been much discussed whether the habitual use of such preserved food is likely to prove deleterious to the health. The general result of the investigations is that, while no preservative should be added to food unless it is absolutely unavoidable, boric acid is less liable to derange the health than most other preservatives. Foods preserved with boracic acid should not be used by delicate individuals or by children, however, and the quantity of the acid used must be strictly limited.

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8. Potassium Chlorate.

The chlorate of potassium, introduced into therapeutics on the erroneous theory that it would supply oxygen to the tissues, has been used

very extensively for its effects in certain diseases of the mouth. It was supposed to be entirely devoid of poisonous properties, but was shown by Jacobi to give rise to very grave and even fatal symptoms in some instances. But the conditions which determine their appearance are not universally present, for very often large quantities have been taken with impunity.

Symptoms.—The chlorates have a cool, saline taste, which persists for a long time owing to their being excreted in part in the saliva. Concentrated solutions may cause nausea and vomiting from their local salt-action in the stomach, and their absorption is often followed by considerable diuresis from a similar action in the kidney. In the great majority of cases no further effects are observed.

In some individuals, however, symptoms arise from a single large dose, or from smaller quantities taken repeatedly. In **Acute Chlorate Poisoning**, the first symptom is often prolonged and violent vomiting, with pain in the stomach region; diarrhœa and a dark cyanotic color of the skin and mucous membranes follow, the respiration is at first dyspnœic and then weak, the pulse quick and feeble, sometimes irregular. The patient complains of headache, giddiness and muscular weakness, is restless, and eventually becomes comatose before death.

In **Subacute Poisoning**, vomiting and diarrhœa are also observed, and the vomited matter often contains large quantities of bile, less often blood. There may be complete anuria for some time, or the urine is scanty and at first dark colored, then deep reddish-brown; it contains hæmoglobin, methæmoglobin, and hæmatin in solution. On standing, it deposits casts of brown amorphous particles, which arise from the destruction of the red cells of the blood, and chlorates are contained in it in considerable quantity. The methæmoglobin may disappear from the urine after one or two days, but the casts remain longer. The skin is often icteric in color, and in some cases erythematous eruptions have been observed. Headache, muscular weakness and abdominal pain are complained of, and uræmic symptoms may arise—delirium and convulsions, or confusion and coma. Death has followed from these last as late as a week after the first symptoms of poisoning were observed, but in several cases complete recovery has followed even the gravest symptoms.

Action.—These symptoms arise from the action of chlorates on the red cells of the blood and especially on the hæmoglobin. When chlorate solution is added to blood in a test-tube it slowly forms methæmoglobin and hæmatin, and the blood assumes a chocolate brown color. Later, the red cells tend to become laked and the methæmoglobin is freed in the serum. This action on the blood is generally ascribed to the oxidizing properties of the chlorates, for other oxidizing agents have the same effects; some oxidizing agents induce marked hæmolysis with little methæmoglobin, while in others the latter feature is the predominating one. There is, however, some difficulty in explaining the chlorate action by oxidation, for these salts are very stable and have practically no oxidizing action at body temperature.

When this transformation of the hæmoglobin takes place in the vessels, asphyxia results from the inability of the blood to carry available oxygen, and this is unquestionably the chief cause of the symptoms and of the fatal issue in the most acute form of intoxication. When a considerable amount of hæmoglobin is transformed, but sufficient remains to continue the respiration of the tissues, the subacute form of poisoning results from the hæmolysis; the hæmoglobin and fragments of the corpuscles obstruct the renal tubules with masses which may appear as casts in the urine, or may cause complete suppression; the fatalities in subacute chlorate poisoning appear to be the result of these renal changes. Some of the products of the hæmoglobin are deposited in the liver and spleen and often cause enlargement of these organs; the bile pigment is increased in amount and the bile passes through the duct with difficulty and this leads to the absorption of bile and jaundice.

The hæmoglobin of most animals seems equally easily transformed to methæmoglobin by chlorates when it is dissolved in water, but the blood-corpuscles of the rabbit and guinea-pig resist their action much more than do those of the dog and of man, which are more readily permeable by the chlorate.

Chlorate has little or no direct effect on the central nervous system or the circulation, though these are secondarily affected by the asphyxia and renal changes.

Very little chlorate is reduced in the blood and tissues, for 90–96 per cent. of the amount administered has been recovered from the urine. Small quantities appear also in the saliva and in other secretions, such as the perspiration, milk, tears, and nasal mucus, and some has been found to pass from the mother to the fœtus *in utero*.

Chlorates hardly retard the growth of bacteria in cultures more than other indifferent salts, and no adequate explanation has been offered for their use in infections of the mouth and throat.

The **Bromates** and **Iodates** have been seldomer the subject of investigation than the chlorates, and are not used in therapeutics. The iodates are more poisonous than the bromates and these again than the chlorates; the iodates destroy the red cells more rapidly but form less methæmoglobin than the chlorates in test-tube experiments. Iodates induce fatty degeneration of the liver and congestion and extravasation in the alimentary tract. Some iodide is formed from them in the body.

The action of the **Perchlorates** has been examined by Kerry and Rost. In the frog the perchlorate of sodium ($NaClO_4$) induces fibrillary twitching and clonic contractions of the muscles; the muscle curve is prolonged in the same way as by veratrine, and rigor eventually follows as in caffeine poisoning. The reflex excitability is increased and the heart is slow and irregular. The effects of the perchlorate on mammals differ considerably in different species; in the rat, mouse, and guinea-pig the reflex excitability is enormously increased and tetanic convulsions may arise from this action; in the cat a certain stiffness, muscular paresis and tremor can be made out after the injection of large quantities of perchlorate, but these animals as well as the rabbit and dog are not easily killed by it.

Potassii Chloras (U. S. P., B. P.), ($KClO_3$), 0.25 G. (4 grs.); B. P., 5–15 grs. Trochisci Potassii Chloratis (U. S. P., B. P.) contain 0.15 G. (0.2 G., B. P.) chlorate of potassium in each lozenge.

The chlorates are colorless prismatic crystals with a saline taste, and are given in solution or in lozenges when used internally. The dry salts form explosive mixtures with organic or other reducing substances, and such mixtures are therefore to be kept cool, and ought not to be ground together, as heat and pressure are liable to cause explosions.

Therapeutic Uses.—The chlorate of potassium is used chiefly as a mouth wash and gargle in irritable conditions of the mouth and throat, such as aphthæ, and in the tenderness and ulceration of the gums and mouth induced by the prolonged use of mercury. It may also be given as a prophylactic to lessen stomatitis when mercury is being prescribed. In catarrh of the throat it is often used with apparently good effects. It is rarely employed in diphtheria now.

It is used in 2–4 per cent. solution, or the official lozenge may be prescribed. In children a somewhat stronger solution with syrup or honey may be used to brush out the mouth, but care should be taken that none is swallowed. The local action of the chlorates has not been explained, and it may be due to the salt-action in part, though not wholly. It has been suggested that they are oxidizing disinfectants, but there is no reason to suppose that they are changed here any more than in the tissues in general. It is not impossible that equally satisfactory results might be obtained by the use of the chlorides or nitrates. Chlorate of potassium has been given internally in cases of diphtheria and in some diseases of the mouth, but it does not seem to have any therapeutic value unless when applied locally. Some benefit may arise from its contact with the mouth and throat in the process of swallowing and from its excretion in the saliva. In addition the internal administration of the chlorate is liable to induce dangerous poisoning.

Poisoning.—The fatal dose of chlorate varies extremely, as little as 1 G. (15 grs.) having proved fatal in a child, while 40–50 G. (10–12 drs.) have been swallowed by adults without marked symptoms. Chlorate poisoning is now very rare; it is said to be more liable to occur in nephritis than in normal persons. As a general rule symptoms appear only two to three hours after the drug has been taken, and the treatment is purely symptomatic—central nervous stimulants, ice for vomiting etc.; alkalies may be given to lessen the formation of methæmoglobin and diuretics and large amounts of fluid to flush out the kidneys.

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9. Iodine.

Iodine has recently been used largely to disinfect the skin before operation, as it is found to penetrate readily into the pores and has a powerful germicidal action. Its irritant effects preclude its more general use. It is generally employed in the strength of $2\frac{1}{2}$–5 per cent. in 10 per cent. potassium iodide solution or in alcohol, and is painted on the site of operation a few minutes before the incision is made.

10. Iodoform.

A number of iodine compounds have been introduced into therapeutics as applications to wounded surfaces. The most widely known of these is Iodoform (CHI_3), which corresponds in its chemical structure to chloroform, and has been used very extensively in surgery; it formerly gave rise to poisoning repeatedly.

Iodoform has no marked **Local Action** on the skin or mucous membranes. Some persons have a special idiosyncrasy for it which betrays itself in an eruption developed in the skin near where iodoform has been applied; Bloch states that a skin graft from these persons implanted in a normal individual continues to show this reaction, but believes that the idiosyncrasy is not limited to iodoform but extends to many other methyl compounds. It seems to have some anæsthetic action, when applied in large quantity to wounded surfaces. Iodoform was at first applied to wounds in the belief that its **Antiseptic** properties were equal to or even exceeded those of carbolic acid. But cultures of bacteria are not prevented from developing by the addition of iodoform. It has therefore been suggested that while iodoform in itself possesses no antiseptic virtues, the iodine formed from it in the wound may retard the growth of septic germs; but microbes drawn from wounds under iodoform treatment are not retarded or weakened in their development. Some of the advocates of the iodoform treatment, therefore suppose that it diminishes the secretion of the wounded surface and thus affords a less suitable medium for the growth of the germs; in this relation it may be mentioned that Binz found the emigration of the leucocytes from the bloodvessels hindered by the local application of iodoform. Finally iodoform may retard the growth of microbes to some extent by forming a crust over the wounded surface, and mechanically preventing them from penetrating to it.

Symptoms.—The symptoms of iodoform intoxication in man generally set in with anxiety, general depression and discomfort. The patient becomes sleepless and restless, complains of giddiness and headache and often of the taste and odor of iodoform in the mouth and nose. The pulse is generally greatly accelerated, and a rise of temperature is said to have occurred in some cases in which no septic poisoning could be found to account for it. The depression deepens into true melancholia accompanied by hallucinations, the patient often suffering from the illusion of persecution, which may induce him to

attempt suicide. As a general rule this melancholia is followed by attacks of violent delirium and mania, lasting for hours or days, and in fatal cases, by collapse and death. In other cases the condition has passed into permanent insanity and dementia. A rarer result of the absorption of iodoform is deep sleep passing into stupor and collapse without any symptoms of cerebral excitement.

In milder cases of poisoning the patient suffers only from the unpleasant taste and odor, from headache and not infrequently from nausea and vomiting.

In the dog and cat iodoform generally causes deep sleep and stupor, with lessened excitability of the spinal cord and of the motor areas of the brain; but after large doses excitement and convulsions of clonic and tonic types have been observed. In the frog it paralyzes the central nervous system and the heart without eliciting any symptoms of excitement. No narcosis is observed in the rabbit even after fatal doses. After prolonged administration albuminuria is often observed in animals, and the iodine of the thyroid has been found to be increased by iodoform, as by other bodies which free iodine in the tissues.

After fatal iodoform poisoning in man and animals, the liver, kidney, heart and muscles are generally found to have undergone fatty degeneration. In addition, irritation of the gastric and intestinal mucous membrane has been observed, and the epithelial cells are often degenerated. Ecchymoses occur beneath the endocardium, in the kidney and elsewhere, and congestion of the meninges is described.

Absorption and Excretion.—Iodoform is readily decomposed in the presence of alkaline fluids and in protein solutions, and some decomposition undoubtedly takes place in wounds; the iodine liberated combines with the alkalies of the fluids to form iodides, for these have been shown to be present, and iodalbuminates are presumably formed in the same way as by free iodine. Some of the iodoform is perhaps absorbed unchanged. After iodoform absorption, iodine has been shown to be present in the saliva, perspiration and bronchial secretion, as after the ingestion of iodine or iodides; but it is chiefly excreted in the urine in the form of iodides and partly in organic combination. The tissues apparently retain it very tenaciously, for iodides have been found in the urine for more than a month after the administration of iodoform.

In considering the symptoms of iodoform intoxication, it must be recognized, therefore, that a very complex condition is present. Some iodoform may circulate in the blood unchanged and give rise to the cerebral symptoms. Other symptoms are due to the presence of iodine and iodides in the blood and tissues. Lastly, the acceleration of the heart and some other symptoms are due to abnormal activity of the thyroid secretory cells. It is possible that the cerebral symptoms may arise from the thyroid gland through the action of iodoform on it, but this has not been demonstrated.

The intensely disagreeable odor of iodoform and its toxicity have led to the introduction of numerous substitutes. None of these seem

to be very poisonous, and in most of them the iodine of the molecule is not liberated in the wound or tissues. It is of course impossible to state how far they are capable of replacing iodoform, as long as their exact action in wounds is unknown.

The first of these substitutes was *iodol* or tetraiodpyrrol (C_4I_4NH), which has no odor or taste, is insoluble in water, but is absorbed from mucous surfaces and from wounds. It is decomposed in the tissues, and leads to the excretion of iodides in the urine, and in very large doses gives rise to symptoms in animals resembling those produced by iodoform. Others are *aristol* or dithymol-diiodide ($(C_6H_2CH_3C_3H_7OI)_2$, and the potassium, sodium, mercury, and zinc salts of soziodolic acid ($C_6H_2I_2HOSO_2OH$). Iodine compounds of phenol-phthalein are known by the trade names of *nosophen*, *antinosine*, and *eudoxine*. Triiodocresol is known as *losophan*, while *europhen* is a more complex combination of cresol and iodine; *loretin* and *vioform* are derivatives of quinoline containing iodine. (See also under Bismuth and Alum.) These later "substitutes" for iodoform differ entirely from it and from iodol in the fact that iodine is not liberated by the tissues; what value they possess is probably due to their acting as absorbent powders, and precipitated chalk would presumably be as efficient.

Iodoformum (U. S. P., B. P.), iodoform (CHI_3), forms small, lemon-colored crystals, possessing a very penetrating, persistent, and disagreeable odor and taste, practically insoluble in water, soluble in alcohol, ether, fixed oils, glycerin, etc. 0.25 G. (4 grs.); B. P., $\frac{1}{2}$–3 grs. in pills or capsules.

Unguentum Iodoformi (U. S. P., B. P.), contains 10 per cent. iodoform.

Thymolis Iodidum (U. S. P.), *Aristol* ($(C_6H_2{\cdot}CH_3{\cdot}C_3H_7{\cdot}OI)_2$), a yellowish-brown powder; tasteless, odorless, insoluble in water.

Iodol, $C_4I_4{\cdot}NH$, a light grayish-brown crystalline powder, tasteless, odorless, insoluble in water. Dose, 0.25 G. (4 grs.).

Therapeutic Uses.—Iodoform has been used to a very limited extent internally in the treatment of syphilis, and as an intestinal disinfectant. It is chiefly employed in surgical treatment as an application to wounds, skin diseases and burns. In granulating surfaces with a profuse secretion, and in slowly healing abscess cavities, it seems to be especially valuable. It may be applied as a dusting powder, as an ointment, or in gauze or bandages saturated with it. It has been shown that it has very weak antiseptic properties, and many surgeons take the precaution of disinfecting the powder before applying it, and use it for its effect on the tissues of the wound and not for its effects on the germs. Applied in ordinary quantity to small surfaces it seems to be a perfectly safe remedy, cases of poisoning occurring only when large cavities are plugged with it, or when it is applied to very large absorbent surfaces.

Iodoform has been credited with some specific action in tubercular disease, but has proved almost inert toward the bacillus. The favorable results in the local treatment of tubercular abscesses, laryngeal ulcers and similar conditions may with greater probability be attributed to its action on the granulation tissue. In syphilitic ulcers and chancres, iodoform has been used very largely and with good effects.

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11. Chlorine Preparations.

The disinfectant action of many organic substances is intensified when chlorine is substituted for hydrogen; for example, chlorphenol is more powerful than carbolic acid. This is not owing to chlorine being freed from the molecule, but from some chemical property which is not understood and which in chemistry renders trichloracetic acid a more readily dissociated and therefore stronger acid than acetic acid.

But several chlorine compounds have been introduced as disinfectants recently, which owe their value to the chlorine liberated by them. Chlorine itself is a powerful poison to all living matter, including the bacteria and has been used for the disinfection of water and inanimate objects. (See p. 171). It cannot be employed in surgery, owing to its intense irritating action, and volatility. Compounds which give off chlorine more slowly than the solution have therefore been introduced; neutral solutions of sodium hypochlorite have been largely employed to irrigate septic wounds (*Eusol* or *Dakin's solution*) and have proved highly efficient as disinfectants. The strength is measured in available chlorine which should amount to 0.4–0.5 per cent. of the fluid. As the chlorine escapes the fluid becomes slightly alkaline; it is not strongly irritant and does not precipitate proteins and therefore penetrates well and has the advantage that it tends to dissolve necrotic tissue and pus to some extent.

A firmer combination is met with in the *chloramines*, in which the chlorine is attached to the nitrogen of an organic molecule. The best known of these is the chloramine-T of Dakin, a toluene derivative of the formula $(CH_3)C_4H_4SO_2NaNCl$. This chloramine is a white crystalline substance smelling faintly of chlorine, and is used in 1–2 per cent. solution in water for the same purposes as hypochlorite solution. It is more stable than the hypochlorite, does not dissolve necrotic tissue in the same way, nor become alkaline; it is less irritant to the skin surrounding the wound.

Hypochlorite solution and chloramine-T have been used extensively in infected wounds and with good results. They owe their activity entirely to the chlorine which they liberate and which is a general poison to all living matter, but if they are properly applied, the action on the microbes more than makes up for their tendency to damage the tissues of the host. On the other hand their use is necessarily limited to local infections; they cannot be applied to disinfect the tissues as a whole, for they act at least as strongly upon the proteins of the human body as upon the microbes invading it.

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II. Antiseptics Used Chiefly in Skin Diseases.

1. Pyrogallol.

Pyrogallol, $C_6H_3(OH)_3$ the only trioxybenzol that has been largely used, produces nervous symptoms resembling those of carbolic acid, when given in very large doses to animals. In the cases of poisoning which have been observed in man, the symptoms arose almost exclusively from changes in the blood corpuscles. The red-blood cells become shrunken and angular and lose most of their hæmoglobin, which escapes into the plasma and is changed into methæmoglobin; the blood therefore assumes a chocolate-brown color, which may be detected in the living animal by the discoloration of the skin and mucous membranes. If the intoxication is not too acute, icterus follows, and hæmoglobin and methæmoglobin are excreted in the urine. In the blood, fragments of red cells and "shadows," or red cells deprived of their coloring matter, are seen in large numbers, and the spectrum of methæmoglobin can be obtained easily. The kidneys are also affected, and the resulting nephritis is indicated by the presence in the urine of albumin, epithelium and casts, along with the products of the decomposition of the blood. The nephritis may lead to uræmic convulsions, which are sometimes accompanied by the nervous tremors characteristic of this series, and also by dyspnœa and cyanosis from the lack of hæmoglobin in the blood. The formation of methæmoglobin is due to the reducing properties of the drug. Pyrogallol is excreted in part in combination with sulphuric acid in the urine, in part as unknown oxidized products, which give the urine a dark brown or black color, even when no blood pigments are contained in it.

The skin is dyed brown when pyrogallol is applied to it, from the products of oxidation formed.

Pyrogallol (U. S. P.), pyrogallic acid ($C_6H_3(OH)_3$, light, colorless crystals or laminæ when freshly prepared, which rapidly assume a darker color on exposure to light and air. It is very soluble in water and reduces the salts of the heavy metals even in the cold. It is used only externally.

Pyrogallol is used in the treatment of several forms of skin disease, especially in psoriasis, in which it is applied in ointment (5–20 per cent.). It is dangerous to apply it to very large surfaces, however, and many authorities therefore advise the use of chrysarobin in its stead. Pyrogallol ought never to be used internally. Its curative action in skin diseases may be due to its slight irritant and antiseptic properties, but is referred by some to its reducing action.

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2. Chrysarobin.

Chrysarobin is a mixture in varying proportions of neutral bodies which are closely related to the active principles of the anthracene purgatives. It is found in an impure form (Goa powder) in cavities in the Andira or Vouacapoua araroba, a tree growing in India and Brazil. Chrysarobin applied to the skin in a concentrated form, or in susceptible persons, causes itching, redness and swelling, less frequently papular or pustular eruptions; the skin and clothing are stained a reddish-brown color where it is applied. When swallowed, chrysarobin acts as a gastro-intestinal irritant, causing vomiting and purging; some of it is absorbed, and in its excretion by the kidneys it causes in the rabbit nephritis with albumin and even blood in the urine. In man, slight albuminuria has been observed in some instances after its application to the skin; in animals the epithelium of the renal tubules has been found to be necrosed, the glomeruli being less frequently affected. Part of that absorbed undergoes oxidation to chrysophanic acid in the body, but most of it passes through the tissues unchanged.

Chrysarobinum (U. S. P., B. P.), a substance obtained from Goa powder, which is found in the trunk of Andira araroba (Vouacapoua araroba, U. S. P.).
Unguentum Chrysarobini (B. P.), 4 per cent. (U. S. P.), 6 per cent.

Chrysarobin is used in skin diseases, especially in psoriasis, in which it is applied in ointment. Its effects, like those of pyrogallol, have been ascribed to its reducing action. Chrysophanic acid might be used also for this purpose were its isolation not attended with such expense. Some confusion has arisen from chrysarobin having been at first supposed to be chrysophanic acid.

3. Naphthol.

The naphthols, $C_{10}H_7OH$, resemble carbolic acid in their antiseptic action but are much less soluble and less corrosive. Alpha-naphthol has been found to be more strongly antiseptic than the beta compound, and may be more poisonous, as is generally stated, but no satisfactory investigation has appeared regarding this point. Beta-naphthol is several times as strongly germicidal as carbolic acid, and is the form used in therapeutics.

The naphthols are irritating to the mucous membranes when they come in contact with them in solution or in vapor; thus they cause sneezing and coughing when applied to the respiratory passages, and in the course of excretion induce pain in the bladder and urethra with strangury and swelling of the mucous membrane. Large doses cause

symptoms similar to those of carbolic acid poisoning, except that in the dog no convulsions have been observed, and in the other mammals they seem less pronounced. Injected subcutaneously or absorbed from the alimentary canal in animals, they induce acute nephritis with the appearance of albumin and hæmoglobin in the urine, and some nephritis has been caused in man from their external application. They seem to have less effect on the circulation and respiration than the other aromatic antiseptics, but resemble them in tending to destroy the red cells of the blood.

Occasionally naphthol has given rise to imperfect sight and partial retinal degeneration in man, and changes in the eye have been observed repeatedly in experiments on animals in which naphthol was absorbed. The retina is seen to be dotted over with bright points or to contain large yellow plaques. Atrophy of the optic nerve may follow or subretinal effusion, and cataract has been developed in some experiments, from an inflammatory infiltration beginning in the ciliary body and iris and extending into the lens and finally into the posterior surface of the cornea. While the ocular effects in man have never reached this intensity, Hoeve has observed some defects of vision induced by the use of naphthol internally or externally, and cautions against its prolonged use.

The naphthols are excreted in the urine in combination with glycuronic and sulphuric acids, and these combinations and their oxidized products give the urine a reddish-brown color which may become deeper on exposure to the air.

Naphthalin, $C_{10}H_8$, the hydrocarbon from which naphthol is derived, is less soluble and does not give rise to acute symptoms in animals, but after prolonged treatment with it animals suffer from diarrhœa and nephritis, with albumin and casts in the urine. The same changes in the retina are induced by naphthalin as by the naphthols. The antiseptic value of naphthalin is small, but it is oxidized to naphthols in the tissues and these acquire a toxic action, It is excreted in the urine as naphthol and further oxidation products, in combination with glycuronic and sulphuric acid.

Betanaphthol (U. S. P.), Naphthol (B. P.), Beta-naphtol ($C_{10}H_7OH$), white or yellowish-white, insoluble crystals or powder, with a faint phenol odor and a hot taste. 0.25 G. (4 grs.) B. P., 3–10 grs.

Therapeutic Uses.—Beta-naphthol was at first introduced as an external application in various forms of skin disease, in which it is used in ointment (5–10 per cent.). Naphthalin was also employed in the same way, but has not proved so popular. Beta-naphthol has also been given internally as an intestinal disinfectant, but has not been efficacious. It has been employed as an anthelmintic to a limited extent, and apparently with some success, though it has not proved so reliable as some of the older drugs used for this purpose; it may be prescribed as a powder or in capsules. Naphthalin and naphthol ought to be avoided in irritation of the kidneys, bladder or urethra.

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4. Resorcin.

The three dioxybenzols—resorcin, pyrocatechin and hydroquinone—resemble carbolic acid in their effects, but produce a more intense stimulation of the central nervous system, for convulsions have been observed in man after their use. This is especially true for the last two, resorcin being much less toxic than these. Resorcin seems to be equally or more strongly antiseptic than phenol, and is somewhat less poisonous, while the others are more dangerous; it is less irritant and caustic than carbolic acid. All three dioxybenzols are excreted in the urine in combination with sulphuric and glycuronic acids. They are in part subjected to further oxidation, leading to coloration of the urine similar to that seen in carbolic acid poisoning.

Resorcinol (U. S. P.) *Resorcinum* (B. P.), resorcin, metadioxybenzol ($C_6H_4(OH)_2$), colorless, very soluble crystals, with a faint aromatic odor. 0.125 G. (2 grs.); B. P. 1–5 grs.

Resorcin has been applied in ointment (5–10 per cent.) in skin diseases, and has been injected in cystitis and gonorrhœa in solution (1–3 per cent.), but in both cases is liable to produce irritation and pain. As an internal remedy it was formerly used as an antipyretic and as an intestinal disinfectant but has fallen into complete disuse.

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5. Tar.

Long before carbolic acid and its congeners were known, tars and other crude preparations enjoyed a reputation in the treatment of wounds, and some of these have been retained in medicine and are widely used. Among these the tar obtained by the dry distillation of different woods is included; its constituents vary with the source, but the creosols ($C_6H_3CH_3.OH.OCH_3$), guaiacols ($C_6H_4OH.OCH_3$), and other less poisonous aromatic compounds are present in larger quantity than the phenols and dioxybenzols, and wood-tar is therefore less poisonous than carbolic acid, and its simpler homologues. At the same time these higher combinations seem to have the same antiseptic powers as the simpler benzol derivatives, so that several of the crude preparations possess considerable value in surgery and medicine.

Preparations.

Pix Liquida (U. S. P., B. P.), tar, is obtained from the wood of Pinus palustris and other species of Pinus by destructive distillation, and contains a very large number of aromatic bodies mixed with others of less importance.

Oleum Picis Liquidæ Rectificatum (U. S. P.), oil of tar, is a volatile fluid distilled from tar, and consists almost entirely of guaiacols and their compounds. 0.2 mils (3 mins.).

Unguentum Picis Liquidæ (U. S. P., B. P.), 50 per cent.

Tar has been used with considerable success as an antiseptic in skin diseases, in which it may be applied either alone or as an ointment. It is only slightly irritating to the skin, and some absorption occurs, as is often seen by the dark color of the urine. Internally it has been used occasionally as an anthelmintic and intestinal disinfectant, much more frequently as an "expectorant" in cough mixtures. Whether it has any effects on the lungs in these cases may be questioned.

Tar is a valuable disinfectant, which is very generally available and is much cheaper than the purer bodies of the aromatic series. It may be used for the disinfection of excrementa, latrines, etc., where the cost of even crude carbolic acid would be prohibitive.

Nencki u. Sieber. Arch. f. exp. Path. u. Pharm., xxxiii, p. 1.
Ström. Arch. d. Pharmacie, ccxxxvii, p. 525.

Ichthyol is derived from the tar of a bituminous shale which is found in the Tyrol, and which contains the remains of many fossil fishes. It has a high percentage of sulphur, and possesses some antiseptic action, although it is believed to be less powerful than carbolic acid. Applied to the skin, ichthyol causes slight irritation, which is apparently of benefit in some cutaneous diseases, and it has therefore been used extensively for this action. A certain amount of absorption occurs when it is rubbed into the skin, for the sulphur of the urine has been found to be augmented. Taken internally in large quantities, it acts as a gastric and intestinal irritant and produces diarrhœa, but it is only very feebly poisonous.

Ichthyol has been strongly recommended in the treatment of a number of skin diseases, including erysipelas. It is generally used as an ointment containing equal parts of ichthyol and petrolate, but may be used in 10 per cent. or even weaker dilution. Ichthyol has been enthusiastically praised as a remedy in the most diverse conditions, but its sphere of utility has been much restricted of late, and it threatens to disappear from therapeutics altogether.

6. Balsams.

Another ancient treatment of wounds comprised the application of various balsams and some of these still maintain a position in therapeutics, though with increasing difficulty. Balsams are mixtures of resin, volatile oil, benzoic and cinnamic acids and their esters. The chief survivors are *Benzoin*, obtained from Styrax Benzoin and other species, *Styrax* from Liquidambar orientalis, *Balsamum Peruvianum* from Toluifera Pereiræ (U. S. P.) or Myroxylon Pereiræ (B. P.) and *Balsamum Tolutanum* from another species of the same genus.

Benzoin and Balsam of Peru are applied in parasitic skin diseases notably in scabies. And the compound tincture of benzoin (containing benzoin, styrax, aloes, and balsam of Tolu) is still used in doses of 2 c.c. (30 mins.) as an ingredient of expectorant mixtures where the mucus is tenacious and coughed up with difficulty. It was formerly known as traumatic balsam and resembles in composition a number of old remedies which were known as Friar's balsam, Turlington's balsam, Jesuit's drops, etc. Syrup of Tolu is used merely as a flavoring agent.

Many other drugs applied to the skin may exercise some germicidal action along with their other properties, but are discussed elsewhere. (See zinc, lead, sulphur ointments.)

III. Intestinal Disinfectants.

Salol.

Salol, or phenyl-salicylate (C_6H_4 OH COO C_6H_5), may be taken as a type of the drugs used to disinfect the intestine, or at any rate to retard the growth of bacteria in the contents and the wall of the bowel. It is a very insoluble, crystalline body, which has little or no local action in the mouth or stomach, but is decomposed in the intestine by the fat-splitting ferment of the pancreatic juice. Some decomposition also appears to occur in the stomach, at any rate under certain conditions. The products of its decomposition, salicylic and carbolic acids, are supposed to act as antiseptics in the bowel and are then absorbed and produce their usual effects. Salol is regarded chiefly as a substitute for salicylic acid, but the formation of phenol from it in the body must not be overlooked, for in several cases of dangerous poisoning which have been observed under it, the symptoms were those characteristic of carbolic acid, and the urine became dark in color from the phenol oxidation products. In moderate quantities, salol produces the disturbances of hearing observed under salicylic acid, without any symptoms of carbolic poisoning.

Salol (B. P.), Phenylis Salicylas (U. S. P.), phenyl salicylate (C_6H_4-$OHCOOC_6H_5$), a white crystalline powder, odorless or faintly aromatic, almost tasteless, almost insoluble in water, decomposed by the pancreatic juice into salicylic acid and phenol. 0.3 G. (5 grs.); B. P., 5–20 grs., in powder or capsule.

Other salicylic acid compounds, similar to salol, are *betol* or *naphthalol* (the beta-naphthol salicylate), *cresalol* (cresol salicylate), *thymosalol* (from thymol), *guaiacolsalol*. They are less poisonous than salol, but have not been largely used.

Salol has been used to lessen putrefaction in the bowel, and even to act upon the bacilli of typhoid fever and of tubercle infecting the intestinal wall. Kumagawa, however, states that the putrefaction in the bowel as measured by the indican in the urine is unchanged by its administration, and he found enormous numbers of bacteria in the fæces afterward. It certainly seems of little value in typhoid fever or in tuberculosis of the intestine. Intestinal calculi have been formed in a few instances from prolonged treatment with salol, which failed to be decomposed in the intestine and formed masses of considerable size.

Salol has been used to diagnose stenosis of the pylorus, as it was supposed that in these cases the reaction of salicylic acid in the urine would be delayed when salol was given. But some salol is absorbed from the stomach, and the interval before salicylic acid appears in the urine varies widely in normal persons, so that the test is of little value.

Salol has some value as a genito-urinary disinfectant, partly owing to the salicylic acid component and partly to the phenol developed.

It is used as a substitute for salicylic acid in rheumatic fever, and has the advantage of being tasteless and of producing no irritation in the stomach.

On the other hand, the considerable amount of carbolic acid freed by its decomposition has given rise to poisoning in some cases. Externally it is of little or no value as an antiseptic, as it is only active when decomposed by the microbes which it is designed to destroy.

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Lesnik. Ibid., xxiv, p. 167.

Other Intestinal Disinfectants.

Most of the drugs possessing disinfectant properties have been used at one time or another in the hope of reducing the intestinal putrefaction, but have generally been abandoned after a shorter or longer vogue. Among these may be mentioned carbolic acid, corrosive sublimate, resorcin, naphthol and thymol. As has been stated (p. 132), there is little prospect of destroying bacteria imbedded in the wall of the intestine without serious injury to the mucous membrane. On the other hand putrefaction of the contents of the bowel is better treated by their evacuation than by attempts to retard the process in the body.

IV. Genito-urinary Antiseptics.

1. Volatile Oils.

A group of volatile oils is used chiefly for genito-urinary disinfection. The best known of these are the *Oils of Copaiba, Cubebs and Sandalwood*, which resemble each other closely in character. Oil of cubebs and oil of copaiba contain a large proportion of sesquiterpene ($C_{15}H_{24}$), and the oil of sandalwoood has two oxidized substances (santalol and santalal), which can be reduced to a sesquiterpene identical with that of copaiba. In copaiba the volatile oil is associated with one or more resinous acids, and in cubebs there is in addition to resinous acids a bitter substance, *Cubebin*, which is not absorbed from the stomach and bowel and is entirely inactive. Cubebs and copaiba have long been used as genito-urinary disinfectants, while sandalwood oil is a more recent addition to the group, which is less disagreeable to take and has less tendency to disturb the digestion. These oils have the irritant effects on the skin, stomach and intestine common to the class of volatile oils (p. 61), are absorbed readily and are excreted partly by the lungs, but chiefly by the kidneys in combination with glycuronic acid; some oil is unchanged, some is partially oxidized in the tissues.

The products of the oils excreted in the urine appear to have some antiseptic action, for the urine of persons treated with them putrefies more slowly than ordinary urine and the growth of many of the more common germs is retarded by it; thus Jordan found that the urine was powerfully germicidal to a staphylococcus after sandalwood oil had been taken, and this action persisted even when the urine was rendered alkaline; on the other hand the colon bacillus grew luxuriantly; others

have found the gonococcus grow readily in media made up with such urine. Winternitz therefore attributes the undoubted efficacy of these oils in gonorrhœa to their glycuronic componds precipitating proteins and thus acting as slight astringents along the urinary tract, as well as to their antiseptic action.

In large quantities, these oils cause irritation in the bladder and urethra, which leads to a constant desire to micturate, and to much pain and difficulty in doing so; sometimes the pain is so great as to lead to complete retention. When the urethra or bladder is in a state of inflammation, these symptoms are produced by even small doses, so that these oils are generally avoided in the acute stages of inflammation, and only given later when the disease has passed into the subacute or chronic stage. They are used in some inflammatory affections of the bladder, but much more extensively in gonorrhœa.

Copaiba and cubebs both contain resinous acids in addition to the volatile oil, and these possess considerable diuretic powers, and are also credited, along with the oils, with some action on the bronchial mucous membrane, so that they often form constituents of "expectorant" mixtures, prescribed to lessen the secretion of the bronchi. These resins are excreted in the urine, and are precipitated by the addition of acids; this precipitate has sometimes been mistaken for albumin, but can easily be distinguished from it by the addition of alcohol, which redissolves the resin but not the protein. The urine is often found to reduce Fehling's solution from the glycuronic acid combined with the oil. The oil of sandalwood is excreted more rapidly than the others. Copaiba and cubebs are less irritant to the stomach than many of the other volatile oils, but after their prolonged administration (especially in the case of copaiba) symptoms of gastric disturbance sometimes appear in loss of appetite and uneasiness in the stomach. Sandalwood oil is said to be less irritant than the others. Occasionally skin eruptions occur after the use of these oils; they are generally of the nature of urticaria, sometimes of erythema nodosum, and only very rarely is eczema seen. The cause of these skin eruptions is unknown, but they may be due to the gastric disturbance.

Preparations.

Copaiba (U. S. P., B. P.), Balsam of Copaiba, Copaiva, the oleoresin of Copaiba Langsdorffii and of other species of Copaifera. Dose, 1 mil (15 mins.); B. P., ½–1 fl. dr.

Oleum Copaibæ (B. P.), the oil freed from the resin by distillation, 5–20 mins.

Cubeba (U. S. P.), **Cubebæ Fructus** (B. P.), Cubebs, the unripe fruit of Piper Cubeba. 1 G. (15 grs.).

Oleum Cubebæ (U. S. P., B. P.), 0.5 mil (8 mins.); B. P., 5–20 mins.

Oleoresina Cubebæ (U. S. P.), 0.5 G. (8 grs.).

Trochisci Cubebæ (U. S. P.).

Oleum Santali (U. S. P., B. P.), Sandalwood oil, distilled from the wood of Santalum album. Dose, 0.5 mil (8 mins.); B. P., 5–30 mins.

Santalol and *santalal* and some of their compounds have been introduced as *gonosan* and *santyl* (santalol salicylate), etc.

Therapeutic Uses.—As has been mentioned, these drugs find their most extensive application in the subacute stages of cystitis and gonorrhœa. They are also used in bronchial disease with an excessive flow of mucopurulent secretion; less often copaiba is prescribed along with other diuretics to promote the secretion of urine. The cubeb lozenges are sucked in hoarseness and relaxed sore throat, and often give relief owing to the pungent peppery action.

In gonorrhœa the therapeutic agent is undoubtedly the volatile oil, the resin having little or no antiseptic action. The oils and the oleoresins are often administered in capsules, as they have an unpleasant odor and taste, especially those of copaiba. They may also be given as emulsions, and cubebs is sometimes prescribed as a powder suspended in mucilage.

Several other oils have been used as substitutes for Copaiba and Cubebs. Among these may be mentioned Gurjun Balsam, which is obtained from Dipterocarpus alatus, and contains a sesquiterpene and a resin. It has been used in gonorrhœa and as a local application in leprosy. Various peppers have been employed as substitutes for cubebs in gonorrhœa, among them *Matico*, but they have not proved so useful as the three typical oils.

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See also the bibliography of the volatile oils in general.

2. Hexamethylentetramine, Hexamine, Urotropine.

Urotropine, or hexamethylentetramine ($(CH_2)_6N_4$), has no important action itself, but is of interest from its liberating formaldehyde in the course of its excretion in the urine; formaldehyde is a powerful disinfectant, and the small quantities liberated from urotropine are sufficient to prevent putrefaction of the urine for many hours. It seems superior to any other urinary antiseptic, microbes in the urine decreasing in number or sometimes disappearing altogether within a few hours of its administration. Formaldehyde is formed from urotropin only in the presence of acid, and the only fluids in the body which are acid enough to liberate it are the gastric juice and the urine. A certain amount of the urotropine swallowed is decomposed in passing through the stomach, but enough is absorbed unchanged to act in the urine if it is acid; when it is alkaline, urotropine has no disinfectant action in the urinary passages; when, however, in those cases the reaction of the urine is rendered acid by the administration of acid phosphates, formaldehyde is formed from urotropine and satisfactory results follow. Urotropine is readily soluble and permeates freely into most organs and secretions of the body; thus it has been found in the bile, pancreatic juice and cerebrospinal fluid,

and this has suggested its use in infections of these fluids. But there is no evidence that formaldehyde is liberated from it in any of these, and there is equally little ground for believing urotropine is of benefit in infections of the gall-bladder, pancreas, or central nervous system. No symptoms arise from ordinary doses of urotropine, but large quantities have occasionally given rise to pain and discomfort in the bladder, and more rarely to hæmaturia, the irritant here is not the unchanged urotropine but the formaldehyde liberated by it. Formaldehyde forms some soluble combinations with uric acid, and this suggested the use of urotropine in gravel, calculus, gout, and similar conditions, but the results have been disappointing.

Hexamethylenamina (U. S. P.), Hexamina (B. P.), Urotropine ($(CH_2)_6N_4$), is a white crystalline powder, very soluble in water and giving off formaldehyde in acid solution. Dose, 0.25 G. (4 grs.), 5–15 grs., B. P.; to be taken in a glass of water.

Urotropine is used in cystitis and urethritis and to destroy typhoid bacilli in cases in which they are eliminated by the kidney. It may also be given as a prophylactic before a catheter is passed. In order to secure that the urine shall be acid, urotropine is often given along with acid sodium phosphate (1 G. (15 grs.)).

Numerous compounds of urotropine have been introduced of late years by rival manufacturers, but none of these has proved superior to the original drug, and none of them form formaldehyde in alkaline urine.

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3. Minor Genito-urinary Antiseptics.

The salicylates have some effect in retarding the growth of microorganisms in the genito-urinary tract and sodium salicylate and salol (p. 162) have been used for this purpose. Benzoic acid and ammonium benzoate are also used to disinfect the urine, and, as in the case of salicylate, act well when it is acid, but lose their effect largely when it is alkaline. Arbutin, a glucoside contained in the uva ursi, is also credited with some antiseptic properties, but is less used now than formerly. Boric acid and borax are both good genito-urinary antiseptics and differ from the other more active drugs of this class in retaining their disinfectant action when the urine is alkaline. Finally the urine is a much less favorable medium for bacterial growth when it is acid, and anything which promotes the acidity (acid phosphate or benzoic acid), has thus some antiseptic value.

V. Antiseptics in Pulmonary Disease.

Creosote.

Creosote may be regarded as a wood-tar from which the more poisonous phenols and the less volatile bodies have been eliminated, leaving guaiacols and creosols as the chief constituents. Its action is similar to that of carbolic acid, except that it has less tendency to induce nervous symptoms, and is less irritant and poisonous. On the other hand, it seems at least as strongly antiseptic as carbolic acid, and, according to some investigators, far excels it as a germicide. Its chief constituents, the *Creosols* ($C_6H_3CH_3OH.OCH_3$) and *Guaiacols* ($C_6H_4OH.OCH_3$), resemble carbolic acid and the other aromatic phenols in their action. They are excreted in the urine for the most part in combination with sulphuric and glycuronic acids.

Guaiacol is readily absorbed from the skin when rubbed into it and considerable amounts can be regained from the urine afterwards. When large quantities are thus taken up from the skin, they often cause a rapid fall of fever temperature with exhaustion and all the symptoms of mild collapse, followed by shivering and rigor and a return of the high temperature. This condition of poisoning is exactly similar to that seen under other benzene derivatives of simple constitution.

Guaiacol carbonate ($(C_7H_7O)_2CO_3$) is almost insoluble and tasteless, and liberates guaiacol in the intestine.

Preparations.

Creosotum (U. S. P., B. P.) is obtained from wood-tar, preferably from beech tar, and is an almost colorless, oily liquid with a smoky odor and hot, burning, acrid taste. It is slightly soluble in water, and mixes readily with alcohol. It tends to darken in color when exposed to the light. 0.25 mil (4 mins.); 1–5 mins. B. P.

Creosoti Carbonas (U. S. P.), a mixture of the carbonates of the constituents of creosote, chiefly guaiacol and creosol, 1 G. (15 grs.).

Creosote may be administered in pills, capsules, in solution in alcohol, wine, or cod-liver oil, or as a mixture. It ought not be allowed to reach the mucous membranes in a concentrated form, as it is liable to irritate them.

Guaiacol (U. S. P., B. P.) ($C_6H_4.OH.OCH_3$), colorless crystals, or fluid, with an agreeable aromatic odor, soluble in 80 parts of water and in alcohol. Dose, 0.5 mil (8 mins.) in solution in alcohol or cod-liver oil, or in pills.

Guaiacolis Carbonas (U. S. P., B. P.) ($(C_7H_7O)_2CO_3$), an almost tasteless powder, is given in cachets in doses of 1 G. (15 grs.).

Therapeutic Uses.—Creosote is comparatively seldom used except in the treatment of pulmonary phthisis and gangrene, and chronic bronchial inflammation. It is generally given by the mouth in these cases, but has also been injected hypodermically or into the rectum; the vapor is recommended as an inhalation, and some practitioners have injected creosote solution into the trachea, in order to ensure its reaching the lungs. None of these methods are believed to give such

good results as the ordinary administration by the mouth. Guaiacol and guaiacol carbonate have recently been substituted for the creosote and are more pleasant forms. The carbonate has also been employed as an intestinal disinfectant.

The results of creosote medication are still disputed. Many clinicians state that a general improvement follows it in phthisical patients, that the appetite is improved, the cough and expectoration lessened, and that the patient feels stronger and better. On the other hand, others are extremely sceptical as to any benefits arising from creosote, and regard it as merely one of the countless remedies which have been recommended in this condition, and which, after a shorter or longer period of popularity, have passed into oblivion.

It is generally supposed by the advocates of the creosote treatment that the remedy destroys the tubercle bacillus in the lungs through its antiseptic properties. On the other hand, animals infected with tubercle and treated with creosote die as soon as controls which are untreated, and the sputum of phthisical patients treated with creosote is as virulent as that of others not so treated. Besides, the administration of creosote by other ways than by the mouth is said to be much less efficacious. Another explanation of the creosote action is that it acts as an intestinal antiseptic and prevents the secondary infection of the bowel; but it has been objected to this that the other intestinal antiseptics are of little value in tuberculosis. It seems useless to speculate on the method of action until it has been definitely determined that creosote is of value in phthisis, and this can be done only by careful statistical inquiry. The medical profession seems to have much less faith in the efficacy of the creosote treatment than it had a few years ago, when it was not generally recognized that pulmonary tuberculosis is curable by hygienic measures in a considerable proportion of instances.

VI. Disinfectants for Rooms, Furniture, Etc.

1. Formaldehyde.

Formaldehyde (HCOH), the aldehyde derived by oxidation from methyl alcohol, is a very powerful germicide, while it is not very dangerous to the higher animals. The aldehyde is a colorless gas and has been used either in solution in water (*formaline*) or as a vapor. As a germicide it is estimated to be equally efficient with corrosive sublimate, and its volatility enables it to penetrate much more rapidly so that it may be used for purposes for which the latter is unsuitable.

Action.—The vapor is very irritant when inhaled, causing stinging and prickling in the nose and throat, salivation and tears, and bronchial irritation and catarrh. In the few cases of poisoning in man recorded the symptoms were those of gastric irritation and consequent collapse. When swallowed by animals the watery solution produces nausea and vomiting, which are followed by narcosis, coma, and in the rabbit by convulsions and opisthotonos. The respiration in the dog is very greatly

accelerated some time before death, while in the rabbit this is not os marked or is entirely absent. The blood-pressure is increased at first, and the heart is slow from direct action on the cardiac muscle. Formaldehyde is rapidly absorbed from the alimentary tract and also by the lungs but quickly disappears from the blood owing to its oxidation and excretion; some formic acid is said to be formed from it, and formaldehyde has been detected in the urine, the gastro-intestinal secretions, and the expired air.

The powerful action of formaldehyde on microbes and on mucous membranes is believed by Loew to be due to its combining with the amino groups in the proteins, and as a matter of fact, a number of changes have been described in the reaction of proteins exposed to this gas. For example, egg albumen and serum to which formaldehyde solution has been added are not precipitated by heat and are less easily digested by ferments, while casein is not coagulated by the rennet ferment. Some of the ferments (pepsin and diastase) are not affected by small amounts of formaldehyde, while trypsin and papain lose their activity wholly or in part.

Preparations.

Liquor Formaldehydi (U. S. P., B. P.), formalin, a solution of formaldehyde in water containing not less than 37 per cent. of the gas, which may be obtained from it by distillation.

Paraformaldehydum (U. S. P.), $(HCHO)_3$, paraform, a solid polymer of formaldehyde, which is partly decomposed by heat and liberates formaldehyde in gaseous form.

Some formaldehyde may be formed by the incomplete combusion of methyl alcohol, and several lamps have been devised with this object in view, but have not proved satisfactory.

Uses.—Formaldehyde is too irritant to admit of its use as an antiseptic in medicine and surgery, but it has been largely employed to disinfect instruments, furniture, clothes and rooms, which cannot be sterilized by heat. Diluted liquor (4 per cent.) may be used for some of these purposes, or the vapor may be disengaged by distillation from the liquor or by heating paraform. Large rooms filled with formaldehyde vapor and left for some hours are found to be almost completely sterilized, so that cultures of the pathogenic microbes exposed in them cease to grow even when removed from the atmosphere. Novy makes the room to be disinfected as nearly air-tight as possible and distils the formaldehyde into it through the key-hole of the door. He states that the gas disengaged from 150 mils (5 oz.) of 40 per cent. liquor is sufficient for each 1000 cubic feet of space, if the room is closed for ten hours. The odor of formaldehyde may then be removed by sprinkling ammonia solution with which it forms urotropine. The disinfectant action of formaldehyde is increased by moderate warmth, and a longer time must be allowed for it to act if the temperature of the room is below 50° F. Formaldehyde not only destroys the microbes, but also alters the toxins formed by them so that they are no longer poisonous, even in very large quantities.

Formaldehyde has frequently been added to food, especially to milk, as a preservative. Tunnicliffe and Rosenheim found that added to milk in the proportion of one to five thousand, formaldehyde did not seem to be deleterious to healthy children, but in the case of a weakly child the protein waste was increased, and it is certainly not to be regarded as a harmless method of preserving food.

Formaldehyde is not alone in its germicidal action, although it is much more powerful than the other less volatile and less active aldehydes, such as acetaldehyde.

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Tunnicliffe and Rosenheim. Journ. of Hygiene, i, p. 321.

2. Sulphur Dioxide.

Sulphurous acid is a powerful reducing agent, as it becomes oxidized to sulphuric acid, and this renders it poisonous to protoplasm in general, quite apart from its acidity. Sulphurous acid anhydride has accordingly been used occasionally to disinfect rooms and furniture after infectious diseases; for this purpose sulphur is burned in the room, which ought to be rendered as air-tight as possible, and the fumes are allowed to act for several hours before the room is ventilated. The value of this method of disinfection has been called in question, and though sulphurous acid gas is fairly germicidal when it is applied along with moisture, it may be doubted whether it has ever been used efficiently in practice; unless efficient, the procedure is open to the objection that it may lend a sense of security which is quite unwarranted, and may lead to the neglect of other measures. Sulphur dioxide bleaches and rots most materials, and the fumes are fatal to the higher animals, even when much less concentrated than are necessary to destroy bacteria. In order to be of service, at least one volume of SO_2 ought to be present in each hundred volumes of air, and even this concentration is insufficient to destroy the spores of bacteria. Novy[1] recommends 3–6 pounds of sulphur to be burned for each 1000 cubic feet of space; the walls and floor should be sprayed with water, and the room must be kept perfectly closed for at least twenty hours.

[1] *Novy* and *Waite.* Medical News, lxxii, p. 641.

The chief symptoms of poisoning with sulphurous acid solution are those of irritation of the mucous membranes, and if the solution is swallowed these may not differ from those of other irritants.

In poisoning from the inhalation of the anhydride, the symptoms arise chiefly from the respiratory tract. Even in 5 parts in 10,000 it acts as an irritant, causing sneezing, coughing and lachrymation, and in somewhat greater concentration it becomes entirely irrespirable; smaller quantities in the air cause bronchial irritation and catarrh, when inhaled for some time. Sulphurous acid is neutralized and oxidized for the most part to sulphates in the tissues, or probably partly in the course of absorption.

Sodium sulphite (Na_2SO_3) and thiosulphate or hyposulphite ($Na_2S_2O_3$) are rapidly changed to the sulphate when given by the mouth; the liberation of SO_2 in the stomach may cause some gastro-intestinal irritation in man, and in animals vomiting has occurred from it. Injected subcutaneously in the frog they cause muscular weakness and finally central nervous paralysis; in the cat and dog a preliminary stage of vomiting, dyspnœa and restlessness is seen, apparently from direct action on the centre in the medulla and on the heart and vessels. When applied in this way the sulphite is excreted in the urine as sulphate, while the thiosulphate is changed more slowly and from a third to a half may escape by the kidneys unchanged. Solutions of these salts have been used to some extent as antiseptic mouth washes. Their earlier reputation as blood and tissue disinfectants in septicæmia is unmerited and they are no longer employed for this purpose.

3. Chlorine and Bromine.

Chlorine and bromine resemble each other closely in the effects which they induce in all forms of living matter. These may be explained in part by their replacing hydrogen in its combinations in the proteins and forming hydrochloric or hydrobromic acid with the hydrogen set free, in part by their combining with the hydrogen of water and thus liberating oxygen, which then acts on the tissues. These processes are believed to account for the fact that chlorine is a much more powerful disinfectant in moist air than in dry. In the higher organisms all of these reactions probably occur together.

Action.—Chlorine and bromine are general protoplasm poisons; thus 3 parts of chlorine in 1000 parts of moist air are sufficient to destroy the spores of most bacteria in the course of three hours, and the infusoria and the higher plants have been shown to be equally susceptible to the influence of the gas. Even smaller quantities of bromine are disinfectant.

In the higher animals and in man chlorine and bromine act as irritants, causing irritation and redness and even blistering of the skin when applied to it in solution, and eliciting when swallowed intense inflammation and corrosion of the mouth, throat, and stomach, with collapse and all the ordinary effects of gastric irritation. Air containing 1 part of chlorine in 100,000 irritates the eyes, nose, larynx and the deeper respiratory passages; bronchitis, pulmonary congestion and hæmorrhages, coughing and pain in the thorax are induced by somewhat higher concentrations, and exposure to about 1 part in 3000 for

fifteen minutes causes acute œdema of the lungs, which may prove fatal immediately. More dilute vapor may be equally dangerous if the exposure is longer. Chlorine and bromine as such are not used in therapeutics, but have given rise to poisoning in their industrial use, and the former has more recently acquired notoriety from its being used in warfare.

These symptoms of chlorine and bromine poisoning are caused by their local action only; they are changed to hydrochloric and hydrobromic acids, and these again to chlorides and bromides in the course of absorption. Attention has been drawn to a number of cases in which symptoms arose in workmen in chemical factories where chlorine is liberated by electrolysis, or more rarely in others where hydrochloric acid is formed in large quantities. The most marked symptom is an affection of the sebaceous glands, from which the condition receives its name of chlorine acne, but this often induces headache, sleeplessness, loss of appetite, and anæmia. No satisfactory explanation of the symptoms has been given, nor is it known whether the chlorine or some unknown body is the cause (Lehmann, Jacquet).

The **Hypochlorites** disengage chlorine more slowly than solutions of chlorine and are correspondingly less toxic to microbes and the higher forms of life. (See p. 156.).

Preparations.

Calx Chlorinata (U. S. P., B. P.), chlorinated lime, bleaching powder, sometimes erroneously called chloride of lime, is a mixture of calcium hypochlorite ($Ca(ClO)_2$), calcium chloride ($CaCl_2$), lime and water. The hypochlorite is very unstable and gives off chlorine in air, and especially in the presence of an acid. Chlorinated lime forms a white or grayish-white powder, with the odor of chlorine. It is only partially soluble in water and must contain not less than 30 per cent. of available chlorine.

Liquor Sodæ Chlorinatæ (U. S. P., B. P.), solution of chlorinated soda, Labarraque's solution or Javelle's solution, is formed from chlorinated lime and contains hypochlorite of sodium (NaClO) and chloride of sodium. Like the corresponding lime salts, it has the odor of chlorine and bleaches vegetable colors. It must contain at least 2.5 per cent. by weight of available chlorine.

The chlorine preparations are chiefly used to disinfect fæces, urinals and to a less extent rooms and houses; for this purpose chlorinated lime is the most suitable, especially when acid is added to it in excess. The room ought to be hermetically sealed, and the fumes are of no value as disinfectants unless they are present in such quantity as to render the air quite irrespirable. They have the disadvantage that they bleach most of the colors used in dyeing, and fail to penetrate in sufficient quantity into the clothing, which they also corrode to some extent. Chlorinated lime exposed in the sick-room merely serves as a deodorant, and has no disinfectant value, but has the disadvantage of giving a false feeling of security like other similar measures. Chlorine seems inferior to sulphurous acid anhydride, and still more so to formaldehyde as a disinfectant, not from its being weaker in action, but because it is more difficult to apply in sufficient quantity. Chlorinated lime can, however, be applied in urinals and closets, where both these disinfectants

are unavailable. Here again it acts as a deodorant, while its disinfectant value is smaller.

Chlorine in the form of hypochlorite has proved effective in destroying the germs in drinking water; it should be added in such amount as to leave about one part of free chlorine in a million of water. A compound which has recently been introduced for the same purpose is *Halazone* ($Cl_2N.O_2SC_6H_4COOH$) which is efficacious in about 4 parts per million and is more stable and more easily transported in small quantities than the hypochlorites (Dakin).

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4. Other Disinfectants.

Many other substances may be employed as disinfectants of urinals, latrines, fæces, etc., the chief determining consideration being the cost of the material in most cases. Thus tar, or crude carbolic acid may be used to disinfect fæcal matter, and unslaked lime is applied to bodies in epidemics in the hope of preventing the liberation of infectious organisms. The most certain disinfectant, where it is available, is moist heat, which is generally used to disinfect clothes and bedding which have been in contact with infected persons.

PART II.

SUBSTANCES CHARACTERIZED CHIEFLY BY THEIR ACTION AFTER ABSORPTION.

I. NARCOTICS OF THE METHANE SERIES.

ALCOHOL-CHLOROFORM GROUP.

A LARGE number of the simpler methane compounds of the open-chain series cause depression of the central nervous system, more especially of the cerebrum, and some of them are perhaps the most extensively used of all drugs, for among them are the universally used surgical anæsthetics, the soporifics, and alcohol. The general action of all of these is similar in character and consists of a first stage of imperfect consciousness and confused ideas, followed by one of wild excitement, and eventually by complete unconsciousness, which may terminate in death. The second stage is much more marked after some of the series than after others, and is often entirely absent. It has given rise to the theory that these drugs stimulate the nerve cells before paralyzing them, but an alternative explanation is that the functions of control and inhibition are lessened, and the centres of motion are thus left free and act more strongly than normally. This question has been most discussed in regard to alcohol, and will receive greater attention under that heading.

The action on the central nervous system is elicited by comparatively small quantities of these drugs, but other forms of living matter are also affected by them in somewhat greater concentration, and their action may in short be considered as coextensive with life, though in man and the higher animals the symptoms from the brain predominate.

The different members of the group vary greatly in their chemical affinities and in their tendency to enter into chemical combinations, and no relation can be found between their narcotic action and the presence of any one radical. This suggests that their effects depend on the properties of the molecule as a whole, and not on a chemical combination being formed with any constituent of the tissues. A very interesting view has been suggested by Meyer and Overton, who attribute the common action of these narcotics to a common physical character. They point out that practically all of them are more soluble in oils and lipoids than in water and that when one of these drugs in watery solution

meets an oil or lipoid it passes from the water to the oil and remains dissolved in it. The same process occurs when these drugs are carried in the blood; they tend to leave the watery plasma and to accumulate in the lipoids of the body, and as the nerve cells are richest in lipoids, the narcotics accumulate in the brain. This is a purely physical process and the amount of the drug taken up from the blood is determined by its relative solubility in the lipoids and in the blood (*coefficient of partition* between oils and water). According to Meyer's view, the presence of the drugs in the lipoids renders these more fluid and thus changes their relations to the other constituents of the cells; this derangement of their normal condition impairs the function of these cells and lessens their activity, that is, causes narcosis. This very attractive theory has been supported by a number of experiments and serves to explain a large number of observations; the accordance of the coefficient of partition and the narcotic power is seen to be very close, especially when members of a homologous series are compared; for example, the narcotic action of the simple alcohols rises from methyl and ethyl alcohol through propyl and butyl alcohol to amyl alcohol, which is the most powerful of the series, and the tendency of the alcohols to pass from water into oil rises similarly. On the other hand when the hydroxyl groups of the alcohols are increased, as in the series ethyl alcohol, glycol and glycerine, the partition coefficient between oil and water falls, and the narcotic action declines.

The experiments of Meyer, Overton and their followers suffice to show that these physical properties are factors in the narcotic action. But these are not the only determining influences. For when the relative narcotic action of less nearly related bodies is compared, the dependence on the partition coefficient is less exact; for example, the relative coefficients of partition of alcohol, chloral and acetone are approximately 1 : 2 : 6, but their narcotic action is 1 : 16 : 1. There is evidently some unknown factor which plays an important rôle in determining the action, besides the solubility coefficient. It seems likely that the distribution in the tissues, and the concentration of the narcotics in the central nervous system is largely determined by the relative solubility in water and lipoids, but that after the narcotics have penetrated into the brain cell the effects depend on some further quality which is still unknown.[1]

Various suggestions have been made of late years as to the nature of narcosis. The old view that it was due to changes in the blood supply and to anæmia of the brain has long been abandoned, since it was shown that the brain of a frog in which the blood was replaced by saline solution, could still be anæsthetized. There is no question that the action of the narcotics is a direct one on the nervous structures, and that the changes in the brain circulation, which are

[1] A suggestion has been made that these narcotics may act by changing the surface tension of the cell contents and thus disorganizing the life processes. It seems clear that this will not serve to explain every case, however ,and in fact is less satisfactory than the Meyer-Overton view. It appears unlikely that any one physical property determines the action of these bodies, though the sum-total of the physical properties may suffice to do so.

similar to those in normal sleep, are the result and not the cause of the narcotic action.

There is an increasing tendency to attribute narcosis to changes in the synapses between neurons; the passage of impulses from one cell to another is believed to be impeded and each neuron remains isolated from the influences to which it is normally subject and which have been developed and strengthened in the course of evolution and education.

Verworn believes that narcosis arises from the arrest of the oxidations in the cells, and in many instances a lessened oxidation has been shown to be present during narcosis. But on the other hand narcosis may be induced in cells which live in the absence of oxygen (intestinal parasites and anaërobic microbes), and cases are known in which narcosis is not accompanied by lessened oxidation. The decrease in oxidation which is seen in narcosis may thus be the result and not the cause of the action.

Lillie holds that the essential feature of narcosis is the diminished permeability of the cell membranes by ions, which can no longer penetrate as is necessary for activity. This diminished permeability may be the result of changes in the lipoids such as are demanded in the Meyer-Overton theory.

Certain features of the chemical constitution of the members of this group have already been mentioned. Thus it is found that, as a general rule, the higher members of a series are more strongly depressant than the lower, provided they are sufficiently soluble in water to be taken up by the blood, and a corresponding increase in the partition coefficient is presented. The increase in hydroxyl groups which augments the solubility in water has the opposite effect, lowering the narcotic action; but if the hydroxyl is substituted by chlorine the narcotic action returns; for example, propionic alcohol (C_3H_7OH) is narcotic but glycerin ($C_3H_5(OH)_3$) is indifferent, while trichlorhydrin ($C_3H_5Cl_3$) is less soluble in water and again acts as a narcotic.

The presence of the carboxyl group (COOH) generally prevents any narcotic action, probably because the acids formed circulate as salts and these cannot penetrate the cells in sufficient concentration. Butyric acid is said to have some narcotic effect, but this may arise from the presence of esters. When hydrogen atoms of these acids are replaced by chlorine or bromine, they acquire a much stronger action; thus acetic acid is practically devoid of narcotic action, while some of the chloracetic and bromacetic acids are narcotic. But their effects on the other organs of the body preclude their use in therapeutics.

This augmented action through the substitution of halogens for hydrogen is seen in many other instances; for example, methane (CH_4) is practically not depressant, but if one, two, or three of the hydrogen atoms in the molecule be substituted by chlorine, forming CH_3Cl,CH_2Cl_2, and $CHCl_3$, the narcotic power increases with each Cl added.

This increased activity of the halogen compounds is not due to any action of chlorine or bromine on the nerve cells, for these elements are not freed from their compounds, which act as unchanged molecules; for example, chlorine is not liberated from chloroform in the tissues, but the whole molecule $CHCl_3$ acts as an anæsthetic, while methane has little action.

The chlorine and bromine derivatives of methane are not only more powerful drugs, but also more powerful poisons than the ordinary compounds; much less chloroform is required to anæsthetize than methane, but much less is required to kill. In addition, these compounds, especially those containing chlorine, seem to have a more powerful action on the heart and circulation and on the metabolism than the others. In other words, the chlorine bodies have a less specific action on the nerve cells and thus involve a larger number of tissues in their effects. (See Chloroform.)

Many methane compounds are not narcotic because they contain more active radicles. Thus ethane (C_2H_6) is a member of the narcotic series, but ethyl nitrite ($C_2H_5O - NO$) cannot be classed with it, because the $-O-NO$ group has a very powerful and entirely different effect; very small quantities of

ethyl nitrite are required to produce the nitrite effect, so that the depressant action is pushed into the background. Members of the methane series often lose their depressant action when combined with nitrogen so as to form substituted ammonia. Thus trimethylamine ($N(CH_3)_3$) has no depressant action, although each of the methyl radicles alone would possess it. Again, the substitution of a member of the aromatic series for one of the fatty substances sometimes changes the action from that characteristic of the alcohol-chloroform group to that of the benzene series. For example, ether ($C_2H_5—O—C_2H_5$) is one of the most valuable anæsthetics, but if one ethyl radical be substituted by phenyl ($C_6H_5— O — C_2H_5$), it loses this property entirely. Others, however, retain their depressant action, as, for example, acetophenone ($C_6H_5—CO — CH_3$).

While the members of this group resemble each other closely in their effects on the central nervous system, they are used for very different purposes in therapeutics and may therefore be discussed in three subgroups: 1, alcohol; 2, general anæsthetics, and 3, soporifics or hypnotics. It must be recognized, however, that there is no hard and fast line dividing these subgroups; for the anæsthetics, chloroform and ether, may be used in small quantities to produce rest and sleep, and would then, strictly speaking, be soporifics; while, on the other hand, chloral and sulphonal, which are generally used as hypnotics, give rise to complete anæsthesia when administered in large quantities.

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1. Alcohol.

Ethyl alcohol (CH_3CH_2OH) has been known in an impure form since the earliest times, and as far back as the history of medicine extends, has been used as a drug. Its medicinal reputation has undergone many fluctuations, by many held to be a panacea, by others it has been considered of importance only as a poison.

Alcoholic liquors are generally prepared by the fermentation of sugars, which either exist preformed in the fruits, or are derived from starch by a preliminary ferment action. The simple liquors (wines and beers) generally contain only a low percentage of alcohol (2–20 per cent.), and the stronger preparations (spirits) are prepared from them by distillation, which raises the percentage to 30–60 per cent. and at the same time removes the non-volatile constituents. Spirits and liquors are not, however, simple mixtures of alcohol and water but contain many other volatile substances, the character of which is little

known, and which are called œnanthic ethers. Some of them have been shown to be higher members of the alcoholic series, while others would seem to be of entirely different constitution.

Action.—The value of alcohol in medicine depends upon three chief points: 1, its irritant local action; 2, its action on the central nervous system, and 3, its value as a food.

The **irritant action** is not so marked as that of many other substances, but is of much greater importance, owing to the habitual use of this drug. It is probably due to the partial precipitation of the proteins of the cells, and is shown by the results of its application to the skin, to wounds, and to the mucous membranes. Applied to the skin in sufficient concentration (*e. g.*, 60–90 per cent.), it produces redness, itching and a feeling of heat like other volatile and irritant substances, such as the volatile oils. Alcohol is, however, much less irritant and at the same time more volatile than these, so that unless its evaporation is prevented, it may produce a sensation of cold and have little or no irritant action; this is especially the case when dilute alcohol is used, no very distinct appearances of irritation of the skin being produced by solutions under 40–50 per cent. In ulcers and other unprotected surfaces, the irritant action is much greater and its application is attended by pain and smarting; the precipitation of the proteins lends alcohol an astringent action in certain concentrations, but if it penetrates deeper it may destroy the cells and it then becomes a corrosive until it is diluted by the fluids.

Its effects on mucous membranes are similar to those on wounds. In the mouth strong alcohol produces a burning, unpleasant sensation which passes to the throat and stomach when it is swallowed, and if the concentrated vapor be inhaled, it causes irritation and reflex closure of the glottis. The effects of alcohol on the digestive functions are so important that they will receive further attention (p. 186).

The action of alcohol on the **Nervous Centres** differs a good deal in individuals. In small quantities it generally produces a feeling of well-being and good-fellowship, along with increased confidence in the powers, mental and physical, of the subject of the experiment. Larger quantities are followed by a certain amount of excitement, marked by laughter, loquacity, and gesticulation. The face becomes flushed and hot, the eyes brighter and livelier, the pulse is accelerated. Even at this stage self-control is partially lost and the will power is weakened. The speech may be brilliant, but it often betrays the speaker; the movements are more lively, but they are often undignified. The loss of self-control is often indicated further by furious outbursts of anger and unreasonableness, or by the indulgence in maudlin sentimentality and sensual fancies. The sense of responsibility and the power of discrimination between the trivial and the important are lost, and the individual has no regard for the feelings of others, or the ordinary conventions of life. If the bout be further continued, the movements become uncertain, the speech becomes difficult and stammering, the walk becomes a stagger, and a torpid slumber follows. Often nausea

and vomiting set in, although these are entirely absent in some cases. On awakening from slumber, very great depression is generally suffered from, together with nausea and vomiting, and want of appetite, which may last for several days and is associated with all the symptoms of acute gastric catarrh.

Very large quantities of alcohol lead to a deep, torpid sleep, which eventually passes into total unconsciousness, resembling the condition in chloroform anæsthesia; the respiration becomes stertorous and slow, and the face, which has hitherto been flushed, becomes pale or cyanotic. This condition may last for several hours and end in death from failure of the respiration, but in other cases the anæsthesia becomes less deep and after a very prolonged sleep the patient recovers. When the stage of anæsthesia is reached, it lasts much longer than that produced by chloroform and ether. It is said that persons rarely or never recover if unconsciousness lasts longer than ten to twelve hours after the drinking bout.

The effects of alcohol vary greatly, however, in different individuals and in the same individual at different times. One person is rendered sentimental, another bellicose, while in a third there may be no appearance of excitement, the first distinct symptom being profound slumber. When drinking is indulged in in company, the excitement stage is a very common phenomenon, but if alcohol is taken without the exhilarating accompaniments of bright lights and exciting companionship, it is much less frequently seen, and the question has therefore arisen how far the environment produces the excitement in alcoholic intoxication.

It may be stated at once that there exist two distinct views as to the action of alcohol on the central nervous system: the one stoutly upheld by Binz and his pupils, that alcohol first stimulates and then depresses the nerve cells; the other championed by Schmiedeberg, Bunge and their followers, that it depresses the central nervous system from the beginning. The symptoms of excitement require no explanation on the first theory, which is rather to be looked on as the natural expression of the facts observed. On the other hand, Schmiedeberg explains them as not due to true stimulation of the motor areas, but as the result of these areas being freed from control by the weakening of the highest functions of the brain—the will and self-restraint. Even the smallest quantities of alcohol tend to lessen the activity of the brain, the drug appearing to act most strongly, and therefore in the smallest quantities, on the most recently acquired faculties, to annihilate those qualities that have been built up through education and experience, the power of self-control and the sense of responsibility.

The question is a most difficult one to decide, for on the one hand it has been shown that the simplest movement is the result of a combination of motor and inhibitory impulses from the brain, while on the other hand the measurement of the relative strength of these impulses is one of the most difficult problems of biology. The advocates of the stimulant action point to the confidence in their own powers exhibited by intoxicated persons, to the brilliancy of the after-dinner speech, and

to the excitement stage as evidences of the increased activity of the brain. But their opponents question whether the confidence is accompanied by any really increased physical strength, and point out that the brilliancy of speech may be due to the environment and to the speaker having lost his habitual shyness and nervousness,[1] and that the excitement is generally absent when the associations are different, or degenerates into a form which more distinctly resembles depression.

The question has been the subject of many investigations, and as the methods have been developed and the difficulties and complexities have been appreciated, the evidence that alcohol is almost wholly depressant has became more definite, while the supposed stimulant action on the nervous system becomes less probable.

The effect on the simple reflexes have been examined carefully by Dodge and Benedict, who find that 30 c.c. of alcohol in man lessens the speed and strength of the knee-jerk and of reflex closure of the eyelids; the reflex arc is therefore depressed by alcohol, and there is no question that this action is central in location.

The amount of work and endurance under alcohol has long been a subject of study from the early experiments of Parkes, who found that those regiments which were not supplied with alcohol marched farther and were in better condition at the end of the day than others to which it had been given. The experiments of Durig in climbing lead to the same result, the total work done being smaller under alcohol and the expenditure of energy greater. Forms of work requiring larger drafts upon the intelligence than the marching of soldiers are also performed less correctly with alcohol than without it; thus typesetters can do more work and make fewer errors when they abstain from its use.

The capacity for work depends not so much upon the actual strength of the muscles as upon the condition of the brain, and these experiments are therefore generally quoted as evidence of the depressant action of alcohol. Their results are not incompatible with the view that alcohol primarily stimulates the nerve cells, however, for Binz and his followers allow that the stimulation is transient and is followed by depression, and if a sufficient time elapse after the alcohol is taken, the stage of depression is elicited and the total work may thus be reduced.

Attempts have been made to measure the work done under alcohol, by recording with the ergograph the work of which a muscle is capable before it is completely fatigued. The best investigations are those of Rivers, who took the precaution of disguising the alcohol with flavors so that the subject of the experiment was unaware when alcohol was given. His results indicate that small quantities of alcohol (5 20 c.c., corresponding to about a tablespoonful and a wineglassful of spirits) have very little effect on muscular work measured in this way. When larger amounts of alcohol were taken, Rivers found that an exceptional amount of work could be performed before fatigue appeared, but he

[1] "Wine does not help us to do a thing well, but makes us less ashamed of doing it badly."

considers this due to the fact that the alcohol could no longer be concealed and the subject was now influenced by suggestion.

In measurements of intellectual work, the factor of suggestion is of still greater moment and the observations of Kraepelin lose much of their importance from the fact that the subjects knew when alcohol had been given them. He states that a person under even a small dose of alcohol makes more errors than usual in adding a row of figures and in reading a series of unconnected syllables, and apparently recognizes letters and words somewhat more slowly. It is interesting to find that the subject of the experiment is quite unaware of the inferiority of his work and is often persuaded that it is unusually good. Kraepelin's later investigations tend to show that this effect of alcohol lasts much longer than is generally recognized, the mental equilibrium being reinstated only twelve to twenty-four hours after even moderate indulgence in alcohol. He leans to the view that alcohol weakens and paralyzes some parts of the brain, while primarily stimulating others, but brings forward no new evidence that this stimulation is not fictitious and really due to the removal of the barriers of self-restraint by the paralysis of higher areas; and Dodge and Benedict in their careful studies on willed movements of the eyes and fingers were unable to find any stage of accelerated nervous activity, and conclude that alcohol only depresses the brain. Most other psychological experiments give similar results, and no unequivocal evidence of the initial stimulant action on the brain has yet been adduced, for each new feature may be interpreted as really due to the depression of controlling or inhibitory functions. Of course, there is no absolutely convincing proof that no stimulation of the motor areas occurs, and no physiological measurement of the activity of controlling areas can be adduced, much less of their depression by alcohol. On the other hand, the effects of alcohol on cerebral activity are very different from those of caffeine, which definitely increases both muscular and mental efficiency, and thus is the typical brain stimulant. Exaggerated importance has been attached to this question from the idea that it is more justifiable to employ a "stimulant" than a "depressant," but in therapeutics this is not a valid argument for or against the use of alcohol.

In the lower parts of the central nervous system the evidences of primary depression are less open to question. For example, the coördination of the finer movements suffers at an early stage in alcohol drinking, long before the generally recognized forms of lack of coördination, such as indistinct speech and staggering, appear. Skilled work is performed more slowly, and far more errors occur in it than in normal conditions, and these errors may lead to serious accidents in industry.

Alcohol has been found to cause a prolonged secretion of the cerebrospinal fluid and to raise the pressure in the subarachnoid space, and it has been suggested that this may account in part for its after effects which have generally been attributed to gastric disturbance.

Acute alcoholic intoxication leads to very distinct alterations in the histological appearance of the cells of the central nervous system, which have been described by Dehio, Stewart, and others. The chief change noted by them consists in replacement of the chromatin network by fine granules, which in turn seem to become dissolved in the general cytoplasm. Staining reagents therefore, give rise to a diffused coloration of the cell rather than to localized masses of color, such as are seen in the normal cell.

The medulla oblongata is the last part of the central nervous system to be acted on by alcohol, or at any rate to undergo complete paralysis. The **Respiratory and Circulatory Centres** preserve their functions long after the occurrence of complete unconsciousness and the disappearance of the ordinary reflexes. The same question has been raised in regard to the respiratory centre, as has been already discussed in the consideration of the brain, and the same two opposing views have been upheld. These are of greater importance as regards the respiratory centre, because the advocates of the stimulation theory advise the use of alcohol in conditions of the respiration in which it is directly contra-indicated if the other view be the correct one. The question here is apparently much more simple, because the activity of the respiratory centre can be estimated directly by measuring the number of the respirations and the amount of air inhaled during each; but a large number of such experiments have been performed with very varying results. If the number of the respirations be counted in a person in the excitement stage of alcoholic intoxication, it is often found to be much greater than normally, but this may be due to the muscular movements and need not indicate any direct action of the drug on the medullary centre. And, of course, this excitement stage is not elicited in therapeutics, and the value of alcohol as a respiratory stimulant must therefore be estimated in cases in which no such excitement is caused. A number of such estimations have been made in man and animals, and in many of these no excitement was produced and in some sleep followed, yet the amount of air inhaled was larger than before the drug was administered; the increase was generally more evident when alcohol was taken during fatigue and exhaustion than in ordinary conditions. This may not indicate a direct stimulation of the respiratory centre, however, for the increase is often not greater than that following an ordinary meal, and may therefore be attributed to the respiratory centre being indirectly affected by the activity of the stomach and intestine. The actual excitability of the respiratory centre may be measured by its response to the inhalation of carbon dioxide, and Loewy's observations by this method do not lend support to the view that the excitability is augmented. A careful analysis of the action on the centre in man made by Higgins by modern methods shows that the alveolar carbon-dioxide tension falls in some cases under alcohol, which indicates that the centre is more sensitive to the presence of this gas in the blood; in other individuals no such change occurs, and in any case the effect of alcohol is small. In most of his experiments the rate of the breathing was not altered and the volume of air breathed per minute was actually lessened.

In the dog, no acceleration of the respiration occurs after alcohol, while in the rabbit, on the other hand, the respiration is much accelerated, and the amount of air inhaled shows a corresponding increase. It is still a matter of dispute, however, whether this arises from direct action on the centre or from the irritation of the stomach, the dilatation of the vessels, and other peripheral effects (Jacquet, Wilmanns, Singer).

In short, there is no unequivocal evidence that the respiratory centre is stimulated to any material extent by small doses, while on the other hand, no depression of the activity of this centre occurs except at a late stage of alcohol poisoning. Alcohol is often said to slow the respiration in fever patients and to stimulate it in cases of shock. In the first case the improvement (when present at all) is probably due to the alcohol lessening the excitement through its narcotic action, while its value in shock is disputed by most careful observers.

From a practical point of view the question is of little importance, for the changes in the respiration induced by alcohol are too small and too inconstant to play any part in the treatment of respiratory disorders.

Circulation.—The pulse is accelerated during the excitement of alcoholic intoxication, but this is due to the increased muscular effort and not to any direct action on the heart for Jacquet has shown that the pulse rate is unaltered by alcohol in normal cases, provided that no excitement be produced by the environment. In animals also, the pulse rate is very little altered by alcohol, except in very large quantities, when it is slowed. The blood-pressure is said to be slightly increased in man in some cases after moderate quantities of alcohol (15–30 c.c.), but in at least an equal number of observations it was found to be slightly reduced, and in many no definite change could be made out (Lieb). In animals the blood-pressure has been found to be slightly increased by some observers, to be reduced by others. Brooks, who has succeeded in registering the blood-pressure painlessly in unanæsthetized animals, found that alcohol given by the mouth increased the arterial tension for about five minutes and then reduced it. When it was injected intravenously or by a gastric fistula, the tension was reduced. Alcohol is believed by some to augment the strength of the heart, but the change is small in extent and inconstant in its appearance. Larger quantities affect the heart in the same way as ether and chloroform, weakening the auricular and later the ventricular systole, and inducing dilatation and slowing of both chambers (Fig. 3). The action of alcohol on the heart is much less than that of chloroform, however, about 200 times as much being required to arrest the frog's heart; and Loeb found that the mammalian heart continues to beat when perfused with two per cent. alcohol.

The flushing of the skin which occurs in alcoholic intoxication indicates dilation of the skin vessels, and this is sometimes accompanied by a very slight constriction of the vessels of the internal organs. These seem to arise from central vasomotor action, but whether it is due to direct stimulation of the centres or arises from a reflex from the stomach, is not yet determined. Very large quantities of alcohol

cause a marked fall in the arterial tension, through weakening the vaso-constrictor centres and the heart muscle, but the quantities of alcohol required to cause any great fall in blood-pressure are far in excess of those used in therapeutics.

On the whole, the action on the circulation of small quantities of alcohol ($\frac{1}{2}$–1 oz.) may be favorable in some conditions, but is so slight and inconstant that it is impossible to regard it as a basis on which

Fig. 3

Tracing of the movements of the ventricle (lower) and auricle (upper) of the dog when a large dose (20 c.c. or $\frac{2}{3}$ oz.) of 50 per cent. alcohol is suddenly thrown into a vein. The levers move upward during systole, downward during diastole. *A*, normal. *B*, injection. The systole of the auricle is very much weakened, the diastole is less affected. The ventricular systole is comparatively little changed, although it also is a little weaker. The effect passes off very rapidly, so that at the end of the tracing both chambers have almost recovered. A very similar effect is seen under chloroform. (Fig. 10.) (The tracing is to be followed from right to left.)

serious therapeutics can be founded. The slowing of the heart which often follows the administration of alcohol in fever, would seem due rather to its diminishing the cerebral excitement than to its direct action on the heart.

Alcohol has little effect on **Muscle** or on peripheral **Nerves** when it is carried to them by the blood, but Lee states that frog's muscle is strengthened by small quantities and weakened by larger amounts. This has been interpreted as indicating that small quantities of alcohol are utilized by the muscle

as a source of energy, while this effect disappears under larger quantities which unfold the toxic action of the drug. And Durig's experiments show that in man alcohol may be utilized for work in the same way as the ordinary sources of energy, such as sugar. When the frog's nerve is exposed to alcoholic vapor its irritability is first increased and later diminished if the quantity applied be large enough. The sensory fibres are said to be depressed before the motor.

The effect of alcohol on the **Digestion** has been the subject of many investigations, both from the clinical and the experimental point of view. There exists a widespread belief in both lay and medical circles that small quantities of alcohol taken before a meal increase the appetite, while after food they accelerate the digestion. It is obvious that alcohol may affect digestion either by altering the activity of the ferments in the digestive canal, or by altering the secretion, movement, or absorption of the stomach and intestine. The digestive power of the ferments outside the body has been found to be practically unaltered when pure alcohol is present in small quantity. But when somewhat larger amounts are added the gastric and pancreatic juices are retarded, and even small quantities of the ordinary wines and beers have this detrimental effect.

The presence of alcohol in the mouth causes (according to Chittenden, Mendel and Jackson) a very appreciable increase in the secretion of the saliva, presumably by reflex action, and a similar increase in the gastric juice may perhaps follow from its local irritant action on the stomach. But, apart from this, it appears to exert a specific action on the secretion after its absorption into the circulation. For when it is injected into the rectum, a profuse secretion from the gastric mucous membrane follows, and when part of the stomach is isolated from the rest of the organ, so that alcohol given by the mouth fails to enter it, this part still shares in the secretion; the pepsin secretion is not correspondingly augmented. It has been further demonstrated that the absorption of fluids from the stomach and bowel is accelerated by the addition of alcohol, while the movements of the stomach are unchanged or diminished by moderate quantities. Alcohol arrests the contractions of the stomach which are characteristic of hunger (Carlson) as distinguished from appetite, but it may not have this effect during digestion.

Digestion in the stomach may thus be influenced in two opposite directions when alcohol is administered in the usual form of wine, spirits, or beer. The action on the ferments is deleterious, while the changes in the stomach wall, the increased secretion and the accelerated absorption may possibly be beneficial in many cases. These two opposing factors may neutralize each other, as in the dog, in which the rate of digestion is scarcely altered, the retarding effects of alcohol on the proteolysis being compensated for by the more abundant secretion of the juice, which continues after the alcohol is absorbed, and therefore after its deleterious effects on the fermentation have disappeared. (Chittenden, Mendel and Jackson.) In man the result varies, the one factor predominating in some cases, the other in others.

Thus, while Kretschy and Buchner found that the digestion of proteins in the human stomach was distinctly retarded by alcohol and beer, Eichenberg, Wolffhardt and others state that small quantities of alcohol or wine accelerate the digestion, and Gluzinsky came to the conclusion that as long as alcohol remains in the stomach the digestion is retarded, but that after its absorption the digestion progresses more rapidly than if no alcohol had been given. Zuntz and Magnus-Levy have shown that the addition of beer to the dietary does not affect the absorption and utilization of the food by the tissues. It is not unlikely that the taste has some influence on the result, that in those who enjoy the taste of alcohol, it induces a more rapid secretion and an improved digestion, while in those to whom it is disagreeable, the secretion is less altered. The narcotic effect on the brain in allaying anxiety and worry may also predispose to the enjoyment of food and improved appetite.

The divergence of opinion exists only in regard to the effects of small quantities, for all are agreed as to the deleterious action of any but moderate doses of alcohol on the digestion. After large quantities (50 c.c.) the irritation of the stomach wall leads to a profuse secretion of mucus, and to gastric catarrh. The nausea and vomiting may arise in part from the local irritation, but it is probable that the nervous centres are also involved directly, for these symptoms occur also under the anæsthetics in which there is no local irritation of the stomach. A large dose of concentrated alcohol sometimes leaves evidence of its irritant action in redness and injection of the mucous membrane, and, it is said, in ecchymoses, but in most cases of fatal poisoning no such appearances are to be observed after death.

Absorption and Excretion.—Alcohol is absorbed rapidly, about 20 per cent. of that ingested being taken up in the stomach and 80 per cent. in the small intestine. The rate of absorption varies with the concentration, strong alcohol appearing more quickly in the blood than the same amount in greater dilution; food delays the absorption when taken at the same time, especially if it contains much fat (Mellanby). The concentration of alcohol in the blood reaches its maximum about an hour after it is swallowed, and then falls slowly as the drug is oxidized and excreted. The course of intoxication follows the curve of the concentration in the blood fairly closely.

It is found in largest proportions in the blood plasma, which contains about twice as much as the corpuscles; Grehant found as much as 6 parts per thousand in the blood of animals, but more than this was inevitably fatal; in a case of deep alcoholic coma in man the blood contained 2.25 parts per thousand (Sweisheimer). Traces remain in the blood for about twenty-four hours, but over 95 per cent. of that ingested is oxidized in that time. The alcohol which escapes combustion in the tissues is excreted by the kidneys unchanged,[1] and

[1] Some of the alcohol in the urine is combined with glycuronic acid in the rabbit, but not in man.

by the lungs.[1] The excretion of alcohol by the lungs is increased by muscular exertion and the consequent hyperpnœa, and that by the kidneys may similarly be increased by large amounts of fluid; and more is excreted when the alcohol is taken on an empty stomach than when it is taken with food; but even in these conditions over 90 per cent. undergoes complete combustion in the tissues. Traces are sometimes found in the sweat and milk, but there is no foundation for the legend that children may be intoxicated, or acquire a taste for strong drink from the alcohol absorbed in the milk of a drunken mother or wet-nurse. The amount and quality of the milk are unaffected by the administration of alcohol (Rosemann). Brauer states that alcohol is eliminated in some quantity in the bile and is then reabsorbed in the intestine; this is more marked in the case of amyl alcohol than in that of ethyl alcohol, and the alcohol in the bile is accompanied by albumin, epithelial cells, and casts of the finer bile ducts.

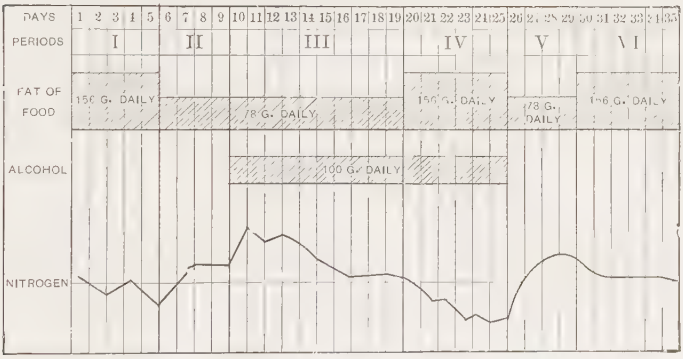
Is Alcohol a Food?—It has been shown that only 5 per cent. or less of the ingested alcohol is excreted, while the rest of that absorbed from the stomach and bowel, amounting to over 95 per cent., undergoes combustion in the tissues. In undergoing combustion alcohol gives up energy to the body, and therefore is technically a food, but this does not imply that it is an advisable food in all conditions. Experiments in which the carbonic acid excretion was measured under alcohol show that no more energy is required for its absorption than for that of other foods, and that alcohol taken in addition to the ordinary food undergoes oxidation instead of carbohydrate and fat, which in turn are used to build up reserves of energy in the body, Alcohol itself cannot be stored in the tissues and is therefore utilized in place of the carbohydrate, which is deposited as glycogen; an increase in the fat of the tissues has been shown to occur in animals treated with alcohol and is a common observation in man (Tögel, Brezina and Dürig). Alcohol, therefore, acts as a substitute for carbohydrates and fat in the food and is utilized like them for the production of heat and work. Higgins has shown that its oxidation begins about five to ten minutes after it is swallowed; the body begins to utilize it as quickly as it does ordinary sugar.

It has long been recognized that when insufficient fat and carbohydrate is supplied to the body, the proteins are drawn upon to make good the deficiency and the nitrogen eliminated rises accordingly. On the other hand, when the fats and carbohydrates of the food are increased, the organism economizes its protein and the nitrogen tends to fall. This is the most accurate method of testing the food value of non-nitrogenous substances, and alcohol has been the subject of a number of such investigations, which have finally decided this much disputed question (Neumann, Atwater and Benedict, and Rosemann and his pupils). The results may be best illustrated by an account of Neumann's first experiment.

[1] Traces of alcohol are exhaled by the breath, but ethyl alcohol fails to escape in this way in measurable quantities. The odor of the breath after spirit drinking arises from the higher alcohols and other by-products present in these and not from the ethyl alcohol.

This lasted thirty-five days, divided into six periods. The proteins of the food and the carbohydrates remained constant throughout, while alcohol was substituted for part of the fat for some time (see Fig. 4). During the first five days the nitrogen excreted was practically equal to that of the food (nitrogenous equilibrium), while during the next four days one half of the fat of the food was omitted and the immediate result was an increase in the nitrogen excreted, indicating that the proteins of the body were being drawn upon to make good the deficit in the fat of the food. The next ten days a quantity of alcohol chemically equivalent to the fat deficit was taken and the nitrogen elimination slowly fell to the normal (equilibrium). In the first five days of this period, however, the nitrogen remained high, showing that alcohol did not at first replace the fats completely. In the fourth period of six days, the same amount of fat was given as at first, while the alcohol

FIG. 4



The effect of alcohol on nitrogen elimination. The wave-line represents the nitrogen excreted. It rises rapidly in the second period when the fat of the food was reduced to one half, but soon falls in the third period where alcohol was substituted. 100 g. of alcohol is chemically equivalent to 78 g. of fat. (After Neumann.)

was continued, and the nitrogen fell much below the amount ingested; *i. e.*, the alcohol again led to a saving of the proteins. Next, both alcohol and fat were omitted for four days and the protein tissues were again drawn upon. Finally the original diet was resumed and the nitrogenous equilibrium was at once restored. From this experiment Neumann drew the conclusion that alcohol can replace a chemically equivalent amount of fat in the dietary, for otherwise the nitrogen would not have returned to the normal toward the end of the third period; and alcohol given along with a sufficient dietary leads to a further economy of the proteins just as additional fat would do; otherwise the nitrogen would not have fallen below the point of equilibrium in the fourth period.

The final result of all these investigations is that alcohol can take the place of some of the fat in the food, and leads to the same economy

of protein as the ordinary non-nitrogenous constitutents of the dietary. The first three or four days during which alcohol is substituted for fat it has little or no tendency to economize the proteins, but this is true of other forms of food also, any sudden change in the non-nitrogenous food leading to a temporary increase in the nitrogen excreted, which persists until the tissues have become accustomed to the new dietary.

Metabolism.—It was formerly supposed that alcohol economized the body tissues in some ill-defined way, by means of a direct action on the protoplasm of the cells; as it was expressed, alcohol lessened the combustion of the tissues. But moderate quantities of alcohol appear to have no action on the general metabolism except that which it shares with other nitrogen free foods. When very large quantities of alcohol are taken, and depression and sleep follow, the combustion of the body is reduced, not through any action on the protoplasm generally, but through the muscular movements being lessened. In the same way, during the excitement stage, the carbonic acid exhaled is doubtless much increased, because more energy and more of the body tissues are used up in the violent movements. But Mendel and Hilditch state that the uric acid of the urine is considerably increased by moderate quantities in man, and this increase is shared in by both the endogenous uric acid and that of the food. This specific action on the uric acid excretion has not been explained. The purin bases are increased to a smaller extent, while the creatinin excretion remains unchanged.

Effects on Growth and Progeny.—Large quantities of alcohol consumed continuously by growing rats were found by Sollmann to interfere with their growth and to lessen the consumption of food, but were not fatal even after several months; but these results have little bearing on the question of human consumption as the alcohol amounted to 2.5 9.5 c.c. per kg., corresponding to about a quart of spirits per day in a man of average weight. Methyl alcohol was more than three times as deleterious.

Stockard found that when male guinea-pigs are intoxicated daily with alcohol for a week, and then crossed with normal females, the litters are often small and present numerous abnormalities, and this tendency may be transmitted through several generations; this indicates severe injury to the germ plasm of the original males, which is inherited by the descendants. Others have made analogous observations, such as that the testes degenerate in both animals and man under the prolonged and excessive ingestion of alcohol; similarly the litters born of animals treated with alcohol are often small and are prone to die early.

Influence on Infection.—Persons addicted to the use of alcohol are known to show less resistance in acute disease and in operations accompanied by shock than more temperate individuals, and in very intemperate cases the prognosis must be guarded in an attack which would ordinarily be accompanied with little danger. This has been confirmed by a number of experiments on animals which were subjected to large doses of alcohol and then inoculated with pathogenic germs (Laitinen). The results have invariably shown a greater susceptibility to infection

and a greater mortality than in control animals which had received no alcohol. A similar effect was observed when toxins were injected instead of bacteria, and great difficulty was encountered in rendering animals immune to the diphtheria toxin if they had previously been treated with alcohol. Various explanations of this reduced resistance have been given, Rubin ascribing it to paucity or inactivity of the leucocytes, while Abbot and Bergey found a reduction in the hemolytic complement, which suggests that the susceptibility to infection may be due to the failure to form the specific complement to the bacterial toxin. Reich on comparing the reactions of the blood of abstainers and non-abstainers found no difference in the phagocytosis of tubercle bacilli, while that of typhoid bacilli was greater in the abstainers and the serum also possessed greater bactericidal powers in these. The resistance of the red blood cells to the action of hypotonic saline solutions was also lower in the non-abstainers. But the differences in all respects were slight. It is often stated that alcohol given in the treatment of infectious diseases must have a similar deleterious effect on the resistance of the tissues, but this has not been shown to be the case.

These clinical and experimental results have raised the question whether the ordinary dietetic use of alcohol in even small quantities (15–30 c.c.) may not lead to impairment of the resistance to infectious disease, and much interest attaches to Laitinen's later work, in which animals were treated with quantities of alcohol corresponding to those habitually used by temperate persons. The general result appears to be that the prolonged use of small quantities in animals (0.1 c.c. per kilo.) may affect their susceptibility to disease, but the average mortality is not greater than that of the controls to which no alcohol has been given.

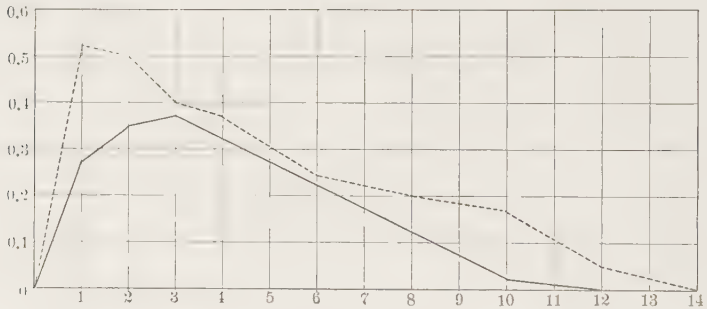
A much more distinct effect from small doses of alcohol, such as correspond to temperate use in man, has been observed by Hunt, who finds that animals thus treated become more susceptible to the action of methyl cyanide. This poison acts in the tissues through being oxidized to hydrocyanic acid, and Hunt believes that the effect of the prolonged treatment with alcohol is to facilitate this oxidation, and that the reaction is evidence of an alteration of the metabolism of the body in this direction. The great importance of this observation lies in the fact that the modification of the metabolism which it demonstrates, arises from the prolonged use of quantities of alcohol which are too small to give rise to definite symptoms of intoxication. Apparently the alteration is associated with the development of tolerance for alcohol.

The **Temperature** of the body falls somewhat after the administration of alcohol, but this is not due to any diminution in the oxidation and in the heat formed, but to the greater output of heat from the dilation of the skin vessels. The fall in temperature is comparatively slight, seldom being more than $\frac{1}{4}$-1° C., but it would seem that exposure to cold causes a greater fall in the temperature after alcohol than in normal conditions; this is perhaps due to the temperature-regulating mechanism being rendered less sensitive by alcohol.

The fall in temperature produced by alcohol is generally accompanied by a feeling of heat, and a thermometer applied to the skin may actually show a rise of several degrees, because more warm blood flows through the dilated vessels. If much excitement and movement follow the ingestion of alcohol, no fall in the temperature may result, the increased heat formed during the movement compensating for the increased output, and in some cases a rise of temperature occurs from the same cause. Very large quantities of alcohol may lead to a fall in temperature of 3–5° C., owing to the lessened movements during unconsciousness.

Repeated doses of alcohol produce **Tolerance**, which, although not so great as that acquired for morphine and nicotine, involves the prescription of double or triple doses in persons addicted to drinking. This tolerance has been shown by Pringsheim to arise in part from the tissues acquiring an increased capacity to oxidize alcohol; and as

Fig. 5



The percentage of alcohol in the blood after giving 5 c.c. per kg. to rabbits. The percentage is indicated on the perpendicular line, the hours after administration along the horizontal. The broken line represents the changes in percentage in a normal animal, the unbroken that in an animal which had acquired tolerance through prolonged treatment with alcohol previously. (Pringsheim.)

oxidation begins almost as soon as absorption, a large quantity of alcohol taken by an habitual drinker may not lead to the accumulation in the blood of a sufficient quantity to induce symptoms of intoxication (Fig. 5). But in addition to this factor, the brain reacts less than normally, for Sweisheimer finds that a given concentration of alcohol in the blood induces greater intoxication in an abstinent than in a tolerant person. In tolerance the amount of alcohol excreted in the breath and urine may sink to less than 1 per cent., all the rest undergoing combustion in the tissues. The close relationship between the narcotics of the fatty series is indicated by the fact that much more chloroform or ether than usual is required to anæsthetize persons in whom a tolerance for alcohol has been established.

Although alcohol seems to increase the **Urine** to some extent, it cannot be said to be a powerful diuretic in itself, and the diuresis may be explained in large part by the quantities of fluid taken with the alcohol and by the accelerated absorption from the alimentary tract. Some of

the spirituous liquors, such as gin, produce a larger secretion of the urine, but this is due to their other constituents, and not to the alcohol.

Alcohol is generally credited with **Aphrodisiac powers**, that is, with increasing sexual desire, although no less an authority than Shakespeare states that it prevents the consummation of sexual intercourse. The unquestionable tendency toward sexual excess observed in intoxication is due, not to any effects on the generative organs, but to the loss of self-control, from the cerebral action of the poison.

Alcohol possesses only a weak **Antiseptic** action, for while the growth of some bacteria is delayed somewhat in a 1 : 1000 solution, many grow abundantly in 4 per cent. alcohol, and some in even stronger solutions. Its disinfectant action has been the subject of a number of researches recently and has been found to vary with the conditions. Dry bacteria may be exposed to absolute alcohol for twenty-four hours without losing their vitality, while 60–70 per cent. alcohol is fatal to them, and also to moist organisms. The explanation of this curious observation seems to be that alcohol fails to penetrate microbes unless in the presence of water. In less than 40 per cent. the action is very slow, so that the limits of alcohol as a disinfectant may be placed at 50–70 per cent.; in this strength it is equivalent to about 3 per cent. carbolic acid, provided that it does not cause large precipitates of protein. Many bodies which are antiseptic when dissolved in water have comparatively little effect when dissolved in alcohol.

Other simple life forms are more susceptible to the action of alcohol than the bacteria, though it does not act on these in such dilution as on the mammalian nerve cell. Even the plants can be subjected to its influence, showing that in sufficient quantity it is a general protoplasm poison. In most cases a stage of increased activity precedes that of depression and this has been used as an argument in favor of the primary stimulant action of alcohol in the brain.

Methyl alcohol, or wood alcohol, has assumed importance lately from a large number of cases of poisoning having occurred from its being substituted for ethyl alcohol as an intoxicant, or in some patent remedies. In animal experiments it is found that given in single doses it is slightly less poisonous than ethyl alcohol, the action coming on somewhat more slowly, but lasting a longer time; the symptoms of gastric irritation are generally more marked than those induced by ethyl alcohol, and very often some convulsive movements are observed (Hunt). When the administration is repeated, methyl alcohol is found much more poisonous than ethyl, and this arises from its slower oxidation and consequent prolonged action. Thus it has been shown that when equal amounts of methyl and ethyl alcohol are administered to animals, over a third of the methyl alcohol can be found in the tissues after forty-eight hours, while of the ethyl alcohol only about one-tenth remains after fifteen hours. About 40 per cent. of the methyl alcohol is oxidized in forty-eight hours, while 25 per cent. escapes in the breath and urine. Pohl has pointed out that while ethyl alcohol undergoes complete combustion in the tissues, methyl alcohol is slowly oxidized to formic acid, most of which is excreted in the urine. As much as 55 per cent. of the methyl alcohol ingested may reappear in the breath, in which it may be detected for a week.

In man the symptoms of wood alcohol poisoning differ from those of ordinary spirits in the marked muscular weakness and defective cardiac action, which are followed by nausea, vomiting, coma, or delirium of a much more intense and persistent character than those seen in intoxication with ethyl alcohol. In a considerable number of cases death has followed from a single dose smaller than would have been fatal had ethyl alcohol been swallowed, and in some cases total and permanent blindness has followed or accompanied recovery. This condition is more often the result of repeated ingestion of the alcohol, however, and is due to optic neuritis and subsequent complete optic atrophy. The large number of cases of blindness or fatal intoxication collected by Buller and Wood demonstrate clearly the danger incurred in the use of this poison internally or even externally, or by inhalation of its vapor. Optic atrophy has been induced in animals repeatedly by the administration of wood alcohol while it is hardly liable to occur from ethyl alcohol.

The **other alcohols** are mainly of interest as impurities of the preparations of ethyl alcohol. They all resemble it in their general effects, but differ from it in toxicity; propyl alcohol is more powerful than ethyl, butyl than propyl, and amyl than any of them. Amyl alcohol, or fusel oil, is present in small quantity in most forms of spirits. It resembles ethylic alcohol in general, but is more irritant locally, and is believed by some authorities to have more deleterious effects in chronic poisoning than pure ethylic alcohol. This is not based on any very satisfactory evidence, however, and all the characteristic symptoms of chronic alcoholism have been produced in animals by pure ethyl alcohol. Furfurol is also present in many forms of spirits, but in such small quantities that it does not play any rôle in the symptoms induced by them.

Preparations.

Alcohol (U. S. P.) contains 92.3 per cent. of alcohol (C_2H_5HO) by weight.

Alcohol Dehydratum (U. S. P.), *Absolutum* (B. P.), absolute alcohol, contains not more than 1 per cent., by weight of water.

Alcohol Dilutum (U. S. P.) contains about 41 per cent., by weight, of alcohol.

Spiritus Rectificatus (B. P.), rectified spirit, contains 90 parts of pure alcohol, by volume, and 10 parts of water (85.65 per cent., by weight, of alcohol). There are four official dilutions in the B. P., containing 70, 60, 45, and 20 per cent. of alcohol by volume respectively.

The **Spirits** are more frequently ordered than these preparations of pure alcohol. Whisky is made by distillation from an extract of fermented grain, brandy from wine, rum from fermented sugar refuse and gin from an alcoholic extract of various herbs.

These spirits all contain, roughly speaking, about 30–40 per cent. of alcohol along with other volatile substances, some of which are alcohols of the same series as ordinary alcohol (butylic, amylic, etc.), while others are of entirely unknown constitution—the œnanthic ethers. Brandy and whisky act very much in the same way as pure alcohol. When freshly distilled they are more irritant and less pleasantly flavored than when kept for some years but do not seem more deleterious. Numerous other preparations containing large quantities of alcohol, such as the spirits of the volatile oils, might also be included in this group, but they are not used, as a general rule, for the same purposes as the alcoholic preparations proper, and their effects are in part due to the volatile oils contained. Some of them have, however, been employed as intoxicants instead of brandy or whisky, and *Eau de Cologne* and other essences have gained a certain notoriety as a means of secret drinking among women. The liqueurs are too numerous to mention, and their composition is extremely diverse. Many of them contain considerable quantities of sugar, and the combination of alcohol and sugar would seem peculiarly deleterious to the gastric mucous membrane. Others, such as cherry water (Kirschwasser), contain hydrocyanic acid, and the others various bodies of the

volatile oil series. None of them seem to have any properties which would recommend their use in therapeutics.

The **Wines** and **Beers** are much weaker preparations of alcohol, the lighter wines (hock and claret) containing about 6–8 per cent. ethyl alcohol, while in sherry and port it may amount to 15–20 per cent. In addition, the wines contain the same volatile constituents as brandy, although in smaller amounts. The red wines contain a form of tannic acid derived from the skin of the grapes, and both red and white often contain considerable quantities of acids, chiefly tartaric acid. The amount of sugar varies with the different wines, and in fact in wine from the same locality but of different seasons. These constituents may lend to the wines a local deleterious action on the stomach, more especially when they are taken habitually. Champagne and the other sparkling wines contain large quantities of carbonic acid, which acts as a stimulant to the gastric mucous membrane. Champagne is considered one of the most "stimulant" of alcoholic preparations, although it contains a very low percentage of alcohol compared with spirits, a fact which is of some significance in the explanation of the "stimulant" effects of alcohol.

The beers are not pharmacopœial, and are less frequently advised than the other preparations. They generally contain a comparatively small percentage of alcohol (4–10 per cent.), along with a large amount of solids. These solids consist mainly of dextrin, sugar, and other starch products, which retard the absorption of the fluid, but are of some value as foods. The hops added in the preparation have probably no action save as bitter stomachics. The alcohol of beer is comparatively slowly absorbed owing to the colloid constituents, and this allows time for fermentation changes in the sugars and dextrins, which may perhaps account for the discomfort produced by malt liquors in persons of feeble digestion. When beers and porter do not derange the digestion, they are the most nutritive of all the alcoholic preparations, owing to the large amount of carbohydrates they contain.

Therapeutic Uses.—Alcohol is used *externally* in very dilute solution as a cooling application to the skin, and in threatening bedsores, in which it is often applied as brandy, whiskey, or dilute alcohol in order to harden the epidermis. It has been employed as an antiseptic and mild irritant to broken surfaces, and if applied to the skin in concentrated form, and especially if kept from evaporation, acts as a rubefacient and irritant. Its use to wash the skin and hands before operations arises from its power of cleansing the skin and removing the oils and fats rather than from its exercising any disinfectant action. In the form of diluted claret it is not infrequently used as an astringent gargle. Strong alcohol (80 per cent. or more) is often injected into nerves or ganglia for the relief of neuralgia, sciatica and similar disorders and leads to degeneration of the nerve fibres and paralysis of sensation and motion, which lasts until the nerve fibres are regenerated after several months. The pain disappears until this restoration is complete, and sometimes permanently. The local nerve destruction arises from the precipitation of proteins and the solution of lipoids.

The indications for the *internal* use of alcohol are ill defined, and cases which one physician would treat with alcohol often seem to progress as favorably without it in the hands of another. It has been prescribed very largely in the past as a "stimulant" under the impression that it increases the activity of the circulation, respiration, and other functions of the body. The basis for this belief has been discussed

already, and the results may be stated shortly: alcohol may promote the vital functions to a slight extent, but this action is very transient and inconstant in its occurrence and is quite insufficient basis for any therapeutic application. The action which lends alcohol its value in therapeutics is not its stimulant but its narcotic action, which allays the anxiety and distress of the patient, promotes rest and sleep, and thus aids toward healing, or at the worst renders illness more tolerable. Small quantities of other narcotics might be substituted for alcohol, but none of them perhaps excel it in producing that spirit of hopefulness and restful confidence which contributes so much to recovery.

One series of symptoms which is often treated with wines is of gastric origin, and is manifested in want of appetite and enfeeblement of the digestion; in some of these cases the alcoholic preparations seem to be beneficial, while in others they appear to be positively harmful. This may be explained by the effect of alcohol on secretion and absorption, only those cases in which secretion is deficient being benefited, but the tastes and mental condition of the patient are a more important factor; if he enjoys the taste and odor of wine, its administration may promote his appetite, and if he is anxious and worried the relief of this condition through the narcotic action of alcohol may restore confidence and improve appetite. In these cases "dry" wines are to be preferred, as the sugar of the sweet wines may irritate the stomach; champagne may be used, and the wine ought to be given immediately before or during a meal.

Cases of hemorrhage, shock and other forms of severe and sudden depression of the heart and central nervous system are very frequently treated by the administration of strong alcoholic preparations, such as brandy and whiskey, this treatment being based upon the belief that alcohol is a cardiac and respiratory stimulant. It is extremely difficult to estimate the value of a remedy in these conditions, and it is possible that it may be of benefit in some cases by lessening the anxiety and pain of the patient if he is conscious. But the beneficial effects of alcohol in these cases has been much questioned in recent years, and the belief that it is of little value is certainly more widely held at present that at any previous time; in experimental shock in animals, Crile found that alcohol generally increased the danger when given in average doses, and that smaller doses had no beneficial effects, but it is quite possible that in man different results may be obtained, from alcohol acting as a narcotic and removing nervous symptoms which would not arise in the lower animals. In unconsciousness it is probably of no value.

"Chill" appears to be a sudden constriction of the vessels of the mucous membranes in the nose and throat which arises reflexly from cooling of a more or less extensive surface of the skin of the trunk or head (Mudd and Grant[1]); the diminished supply of blood lessens the resistance to the invasion of bacteria which may be present in the throat, and chill is therefore often followed by infection and fever. Anything

[1] *Mudd* and *Grant*. Jour. Exp. Med., 1921, xxxiv, 11.

which dilates the skin vessels, at once restores the circulation in the mucous membranes and at the same time relieves the sensation of cold arising from the ischæmia of the skin. Alcohol is often of benefit in chill especially when taken in the form of brandy or whiskey diluted with hot water, and this is obviously due to the dilation of the skin vessels. Other drugs with the same effect are the volatile oils, camphor and opium, especially when given with a diaphoretic as in Dover's powder.

In many cases of acute inflammatory disease, the prescription of alcohol seems to be attended with benefit, while in others it seems rather to increase the severity of the symptoms. No special indications can be given for alcohol in these cases, and the physician must be guided by its effects. It may tend to allay the irritability of the nervous centres, and thus reduce the delirium and slow the heart and respiration by lessening the muscular movement; Cabot and Dening and his pupils state that the administration of alcohol to patients is not followed by any significant rise of blood-pressure, but by a slight fall in most cases. Moreover, the tissue waste is much increased in fever, and at the same time the food absorption is less than normally, so that many of the symptoms may be due to starvation of the tissues. The food-value of alcohol is unchanged by the presence of fever (Ott); it demands less energy from the digestive organs than fats and starchy foods, and has a higher value as a producer of energy than sugar. It cannot supply the place of the nitrogenous foods, but given along with them, may lead to a greater economy of the tissues. Strong wines or diluted spirits are generally employed here and ought to be given in small quantities frequently.

Alcohol was formerly advocated especially in septic conditions, and here it may be of value on the same grounds as in acute fevers, although it does not seem to have any specific action in septic disease, as was once believed. A protest has recently been raised against the use of alcohol in these cases, on the ground that animals subjected to alcohol succumb more readily to infection than controls which have received no treatment, but this increased susceptibility does not seem to be induced by doses proportioned to those in use in modern practice. In addition, this deleterious action may be more than compensated for by its value as a food and by its narcotic effects allaying the nervous irritability and promoting sleep; this narcotic action may very well be conceived to be of benefit to man, while actually prejudicial to animals.

In some chronic forms of nervous disease alcohol may also be of value, although its administration must always be guarded, owing to the tendency to the formation of the alcohol habit. Thus, in some forms of melancholia and of neuralgia it gives relief, and some authorities recommend its use in small quantities in cases of distress of mind from any cause, such as grief, business anxiety or depression; undoubtedly alcohol improves these conditions by its narcotic action on the brain, but the danger of the alcohol habit is so great that many physicians refuse to take the responsibility of prescribing the drug in these cases.

In certain forms of brain defect, notably in epilepsy, alcohol often acts with unusual power and sometimes appears to cause a prolonged nervous disturbance which is very deleterious in these subjects.

In chronic conditions of cachexia and loss of flesh in general, and during convalescence, alcoholic preparations are often advised simply as foods, and in these cases the ales, beers and porters are generally to be preferred to the others, provided always that the stomach is not irritated by them, as they contain other foodstuffs of value in addition to the alcohol.

In the treatment of diabetes by the withdrawal of carbohydrates, alcohol has been advised to maintain the supply of energy, which it does without increasing the sugar of the blood and urine. Here wines or beers are not available, and pure alcohol diluted to about 5 per cent. is the best form; it may be given in quantities corresponding to 5 -10 c.c. of absolute alcohol every hour, and causes no symptoms, as it is completely oxidized in this time, and supplies 600 or more calories per day.

In poisonous snake bite, alcohol is generally administered in enormous quantities, either as whiskey or brandy, but it is really of no value in these cases except as a narcotic.

Alcohol is of value as a mild hypnotic, a comparatively small quantity taken before retiring being often sufficient to secure quiet and refreshing sleep. Beer, or spirits and water, is generally used for this purpose.

Brandy has a certain reputation in the treatment of the milder forms of diarrhœa, while the other spirits have no effect in this condition. The way in which it acts here is unknown.

In the prescription of alcohol, the ordinary spirits, brandy or whisky, are much more frequently advised than the pure preparations, as the latter are more apt to pall upon the taste of the patient. Both of these spirits ought to be diluted with at least an equal quantity of water. The wines are more used in chronic conditions, although diluted spirits may be advised here also. Beers are employed only in debility unaccompanied by gastric symptoms.

Alcohol can be given to children in relatively larger quantities than to adults, and again in old age no such reduction in the dose is required as in the case of many other drugs. Where a tolerance for alcohol has been established, the dose has often to be more than doubled in order to have any effect, and in acute febrile conditions very large quantities of alcohol are often given without intoxication, though it seems questionable whether an equally beneficial result could not be attained with smaller doses. In gastric irritation, most preparations of alcohol are contra-indicated, but champagne is often of benefit in checking vomiting, especially that of pregnancy and of seasickness, this effect being due to the carbonic acid, not to the alcohol. In nephritis and other inflammatory conditions of the genito-urinary tract, alcohol is generally avoided on account of its supposed effects on the epithelium.

In regard to the **Habitual Use of Alcohol** by healthy persons, all authorities agree that it is a luxury, that it is entirely unnecessary for the

growth and maintenance of the body, and that it neither promotes greater healthfulness nor in any way retards the onset of disease. It is true that it is utilized by the body as a food, but its value as such is limited because only small quantities can be taken without disturbance of the nervous system. At the same time it is difficult to prove that the moderate use of alcohol is injurious, for when taken after work it seems to cause no impairment of the capacity for work next day and often seems to remove the sense of fatigue. And in many it undoubtedly promotes happiness and allays the worries and anxieties of life. Attempts have been made to show that even the moderate use of alcohol lessens the resistance to the onset of disease, but these have not been successful. There are, however, two considerations which may be brought against the use of alcohol even in the most strictly limited quantities. The first of these is drawn from the statistics of life insurance, in which it is found that the prospects of longevity are better for total abstainers than for even moderate users of alcohol.[1] The second is that the moderate use of alcohol leads to chronic alcoholism in a certain percentage of persons.

The habitual indulgence in alcohol to excess is more easily intelligible than some other chronic intoxications, for, unlike nicotine, alcohol is taken not only for its local effects on the organs of taste and on the mucous membranes of the mouth and stomach, but also for its action on the brain in numbing the consciousness of unhappiness, and this weakening of the higher sensibilities by drink is generally the object sought by the drunkard. He finds that under alcohol his habitual depression disappears, and he loses the sense of degradation and remorse which possesses him when sober. The depression returns in exaggerated form after the effects of the drug have passed off, but it can be removed again by the same means, and in this way the habit is formed, each successive dose being rendered necessary by the depression produced by its predecessor. This descent into chronic drunkenness is facilitated by the lessening of the self-control, owing to the action of alcohol on the brain. The victim may form the best of resolutions, but his impaired will power and self-control are unable to carry them out.

The symptoms of **Chronic Alcoholism** are unfortunately common, but may be treated better in detail in connection with various forms of disease, with which they are associated more closely than with the effects produced by the medicinal use of the drug. The earliest symptoms are generally observed in the stomach, throat and larynx, and consist of a chronic catarrh, which is often accompanied by skin affections, such as injection of the cutaneous vessels (especially of those of the face), acne, or pustular eruptions. Fatty degeneration occurs in the liver especially, and is said to be accompanied by a marked decrease in the lecithin and other lipoids of the cells. Cirrhosis of the liver is not now believed to be the direct result of alcoholism. Fatty degeneration

[1] There seems no question that there is some advantage in favor of the abstainer, though it is smaller than is generally stated; no explanation has been offered, but it may be that the abstainer is less liable to accidents of all kinds including those of syphilitic infection.

is also found in the arterial walls throughout the body, and favors the development of atheroma and arteriosclerosis, which may lead to small aneurysmal dilatations, ecchymoses, or apoplexy. The heart undergoes more or less fatty change, which is accompanied by dilatation and weakness. In the central nervous system, the nutrition is imperfect owing to the vascular changes, but in addition to this, alcohol has a special action on the neurons, which is betrayed by the disappearance of the chromatin granules, and eventually by shrinkage of the whole cell. These alterations in the central nervous system lead to impairment of memory, self-control and the other higher mental processes. Tremor, convulsive attacks, hallucinations and mania are eventually followed by idiocy and paralysis in the worst forms of the disease. The peripheral nerves seem to be acted on directly as well as through the changes in the centres, for neuritis has been frequently observed, ending in local paralysis. A form of amblyopia commencing by atrophy of the retinal ganglion cells and later extending to the fibres of the optic nerve has recently received some attention; it is much more readily elicited by methyl than by ethyl alcohol. A characteristic result of chronic alcoholism is *delirium tremens*, an acute attack of insanity, which is liable to occur after any shock, such as hæmorrhage or acute disease, but which is said to be also produced by the sudden withdrawal of alcohol, and sometimes occurs without any apparent immediate cause. It is characterized by tremor, perspiration, sleeplessness, fear, excitement, and hallucinations of the various senses, which differ from many other hallucinations of insanity in consisting of the multiple appearance of the same object. These objects are often animals, such as snakes, rats, dogs, but the hallucinations are not confined to those of sight, for whispering voices are complained of not infrequently.

The more severe forms of chronic alcoholism are confined almost entirely to the drinkers of undiluted spirits. Beers and wines seldom cause any distinct lesions in the brain in themselves, unless spirits are also indulged in. The abuse of the weaker preparations of alcohol is always liable to lead to that of the stronger, however, as tolerance is established and the former lose their effect. The combination of spirits and malt liquors is said to be more liable to produce delirium tremens than the abuse of either alone.

The disastrous effects of the abuse of alcohol are seen in the statistics of the hospitals, prisons, and asylums in nearly all countries, but more especially in those in which the population is addicted to spirits. A large percentage of crime is admittedly done under the influence of alcohol or as a direct result of alcoholic excess, which is also responsible for a large part of the poverty and misery of the lowest classes of the population. A considerable proportion of the admissions to lunatic asylums is also often ascribed to alcoholism, although Mott has pointed out that this factor is not infrequently exaggerated. And it must be taken into account that only the more extreme cases come under the categories of criminals or lunatics, and the enormous number of cases of disease directly caused or aggravated by the lesions due to alcohol

escapes recognition. At the same time, it is beginning to be appreciated that chronic alcoholism itself is probably due to a mental defect, so that in a certain number of these cases of insanity and crime, the over-indulgence in alcohol must probably be considered a symptom and not a cause. On the other hand, alcoholic excess aggravates the mental defect in these cases both by its direct action and through the social and economic disabilities which arise from it; and this aggravation of a congenital weakness can be avoided only by abstention from alcoholic beverages. Attempts have been made of late years to demonstrate that the effects of alcohol are hereditary, that the children of alcoholists supply a larger proportion of cases of insanity and crime than those of the rest of the population. It would seem more probable, however, that the alcoholic excesses of the parent have no direct effect on the offspring, except in their nutrition at birth, but that the mental defect which leads to alcoholic excess in the one generation is inherited and leads to crime or insanity in the next. The deleterious effect of the alcoholic habit in the parent on the nutrition of the offspring is a well-established fact. (See p. 190).

The *treatment of acute alcoholic intoxication* is to evacuate the stomach by means of the soft elastic tube. The patient ought to be put in bed and kept warm, as there is a tendency to a marked fall in the body temperature. In case of great congestion of the brain, cold may be applied in the form of ice-bags to the head, and some authorities recommend bleeding. In cases of extremely deep unconsciousness, nervous stimulants, such as caffeine or strychnine, may be had recourse to, and, as a last resort, artificial respiration.

Chronic alcoholism is to be treated by the withdrawal of the poison, and this is best done gradually, as the immediate stoppage may lead to delirium tremens. It is often necessary to incarcerate the patient in some retreat. A large number of drugs have been advocated in these cases, some of them, such as opium, acting as substitutes for alcohol, others (capsicum) replacing the local action on the stomach. The use of opium and other narcotics may, however, lead to a craving for these which is quite as serious as the original condition. Another method of treatment, which appears to be successful in some cases, is the addition of nauseating drugs such as ipecacuanha or apomorphine to the alcohol which is supplied to the patient. The association of nausea with liquor eventually becomes so strong that alcohol in any form becomes distasteful. The organic lesions must be treated individually.

The *treatment of delirium tremens* generally consists in the use of chloral or opium to lessen the excitement. It is often necessary, or at any rate advisable, in these cases to allow small quantities of alcohol, as the sudden withdrawal may aggravate the condition.

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2. General Anæsthetics—Ether and Chloroform.

The term general anæsthetics is employed to indicate substances used to produce unconsciousness sufficiently complete to allow of surgical operations being performed. In the history of medicine there are repeatedly obscure allusions to substances used for this purpose, but it was not until the end of the first half of the nineteenth century that the era of surgical anæsthesia really opened. In 1798 Davy advised the use of nitrous oxide as an anæsthetic, but no practical use was made of his suggestion, and Wells may be said to have rediscovered this property of the gas in 1844, though his efforts to introduce it into general use met with no greater success than Davy's. Long used ether in 1842–1843 in surgical operations, but did not give any publicity to his discovery, and the honor of demonstrating publicly the practical use of ether in surgery must be awarded to Jackson

and Morton in 1846. In 1847 Simpson introduced chloroform to the medical profession as a substitute for ether, over which he supposed it to possess several advantages. Its pharmacological action had been examined some months earlier by Flourens, but Simpson appears to have made his investigations quite independently. Chloroform soon ousted ether in popular favor in Europe, and although in America a considerable number of surgeons continued to use it, ether had practically fallen into complete disuse throughout Europe, save in Lyons, until a few years ago. The continually increasing number of accidents in chloroform anæsthesia has, however, caused a reaction to set in in favor of ether, and it has been once more reinstated as the rival, and perhaps as the superior, of chloroform throughout the world.

Many attempts have been made to introduce other substances of the methane series as substitutes for the two generally recognized anæsthetics, and ethyl chloride is used for short operations. Soon after the introduction of ether and chloroform, nitrous oxide gained a permanent footing as an anæsthetic.

These anæsthetics are invariably given by inhalation and not by the stomach, as it is found that the exact depth of the narcosis can be much more easily controlled by the former method. Both the absorption and excretion of these drugs occur almost entirely by the lungs, according to the ordinary physical laws of the absorption of gases by fluids. The more concentrated the vapor of chloroform in the lungs, the greater is the quantity absorbed into the blood and the deeper the narcosis. By regulating the proportion of the vapors in the air inhaled, therefore, an anæsthesia of any desired depth may be induced. The degree of narcosis and of danger is not indicated by the actual amount of the anæsthetic which has been used, but by the concentration of the vapors which have been inhaled; one patient may in the course of a long operation, inhale and again exhale many ounces of chloroform without danger, while another may be thrown into a position of extreme peril by the inhalation of a few drops of chloroform in concentrated vapor.

Symptoms.[1]—The action of chloroform and ether may be divided into three stages: (1) that of imperfect consciousness; (2) that of excitement; (3) that of anæsthesia.

[1] The poet, Henley, has given the following description of his sensations under chloroform in Lister's wards in the Royal Infirmary, Edinburgh:

Then they bid you close your eyelids,
And they mask you with a napkin,
And the anæsthetic reaches
Hot and subtle through your being.

And you gasp and reel and shudder
In a rushing, swaying rapture,
While the voices at your elbow
Fade—receding—fainter—farther.

Lights about you shower and tumble,
And your blood seems crystallizing—
Edged and vibrant, yet within you
Racked and hurried back and forward.

Then the lights grow fast and furious,
And you hear a noise of waters,
And you wrestle, blind and dizzy,
In an agony of effort.

Till a sudden lull accepts you,
And you sound an utter darkness—
And awaken . . . with a struggle . . .
On a hushed, attentive audience.

The *first effect* of their application is a feeling of asphyxia, which is especially marked in the case of ether, and of warmth of the face and head and eventually of the whole body. The senses become less acute, the patient seeming to see only through a veil of mist, and the voices of those in the immediate neighborhood appearing to come from a distance. Ringing, hissing and roaring in the ears and a feeling of stiffness and of inability to move the limbs herald the approach of unconsciousness. With the exception of the first feeling of suffocation, the sensations are generally pleasant. During this stage the face is generally flushed, the pupils enlarged, the pulse is somewhat accelerated, and the respiration may be rendered irregular by the sense of suffocation, or may be slightly quickened. Even at this early stage sensation is blunted.

The *second stage* of excitement varies extremely in different individuals. In some cases, especially in children, it is entirely absent, and in others its presence may be indicated merely by tremor, by the stretching of the limbs, or by irregularities in the respiration, but in the majority of cases of anæsthesia it is much more marked. It often begins by movements of the arms, designed either to push away the inhalation mask or to enable the patient to rise; soon his other muscles are involved in the movement; he struggles, shouts, sings, groans, or bursts into laughter. The movements are not generally uncoördinated, but are evidently the result of some dream-like condition of the consciousness, and these dreams are often connected with the operation or with the surroundings of the patient before the inhalation began. They are, of course, determined largely by his natural mode of thought—one person prays aloud and sings hymns; another abuses the surgeon, the hospital and all his recent surroundings, while yet another is overcome with the fear of impending death and laments his unfortunate position. In this stage the pulse is generally quickened, the skin is flushed and often cyanotic, the respiration is extremely irregular from the struggling, and the pupil continues somewhat dilated. If the anæsthetic be pushed, however, the movements soon become less powerful, the muscles relax and the stage of anæsthesia sets in.

In the *third stage* the face assumes a calm, death-like appearance from the relaxation of the muscles, the pupils contract somewhat and may not react to light. The reflexes disappear, one of the last to go being the closure of the eyelids on touching the cornea. The pulse is generally somewhat slow and weak; the face is pale in chloroform anæsthesia, but may be suffused and cyanotic after ether. The respiration is slow and shallow, but regular. This stage of anæsthesia may be kept up for hours without much change by the repeated inhalation of small quantities, although the pulse tends to become weaker and the respiration shallower unless the greatest care be exercised, and the body temperature invariably sinks. When the administration ceases, the patient passes again through the excitement stage, which, however, is not generally as violent, although it may be more prolonged, and then often sinks into sleep, which lasts several hours.

Not infrequently, however, instead of sleep, nausea, giddiness and vomiting continue for some time after the return of consciousness.

In surgical anæsthesia, the third stage is often interrupted by short intervals of semi-consciousness and slight excitement if the administration of the drug be interrupted occasionally.

The use of these drugs is so widespread, and the indications of danger in anæsthesia are so important that a more detailed account of the alterations observed during their use in the human subject may be inserted here.

The *pulse* is often somewhat accelerated before anæsthesia, owing to the anxiety and nervousness of the patient, and in the first, and still more the second stage, a further acceleration may occur from the same cause, although in other instances marked slowing of the pulse may set in here from reflex stimulation. When the stage of anæsthesia is reached, the pulse becomes slower and weaker than normally, and this change increases with the depth of the anæsthesia produced. It remains perfectly regular, however, in ordinary cases, and, in fact, unless the anæsthesia has reached an extremely dangerous stage. In very prolonged, deep anæsthesia the weakness of the pulse may give rise to anxiety, especially if the temperature of the body is very low.

The *respiration* is generally fairly regular until the second stage, save that the breath may be held for some time owing to the choking sensation, and a deep gasp may follow; coughing is occasionally met with, especially in the first stage of ether anæsthesia. In the second stage, the respiration is extremely irregular when the excitement is violent. The respiratory muscles are involved in the general convulsive movements, so that no air whatever can enter the lungs for several moments, and then several deep gasps may follow and load the blood with concentrated vapor. During the third stage the respiration becomes regular but shallower and slower than before the anæsthetic was applied, and if the operation be prolonged, the weakness of the respiration may give rise to alarm. Large quantities of saliva and mucus may hinder the respiration and require removal, and a common occurrence is the production of snoring from the falling back of the tongue, and this may also require attention.

The behavior of the *pupil* is of some importance in anæsthesia. During the first and second stages it is generally somewhat dilated, but as soon as complete unconsciousness is attained, it becomes rather narrower than it is normally. As the patient recovers, the slight dilatation slowly recurs; if the respiration and circulation be dangerously weak, rapid dilatation occurs in most cases. Dilatation of the pupil in the stage of anæsthesia, therefore, indicates danger, unless it is accompanied by symptoms of returning consciousness, such as reflex movements and vomiting.

The *hypersecretion* of saliva and of bronchial mucus is much more marked in ether than in chloroform anæsthesia. *Vomiting* occurs so frequently during anæsthesia that it may be looked upon rather as one of the attendant phenomena than as an accident. It may set in prac-

tically at any time, but is more often seen in the late than the early stages, and more frequently when the anæsthetic is applied soon after a meal than when the stomach is empty.

Action.—The action of ether and chloroform on the **Central Nervous System** is evidently similar to that of alcohol, although the phenomena habitually elicited in the use of the former are very rarely produced by the latter. In all three intoxications, however, there may be observed the stages of lessened consciousness, of excitement, and of total unconsciousness. Alcohol was formerly administered in very large quantities to allow of surgical procedure, and ether has not infrequently been used as an habitual intoxicant.

These anæsthetics produce the same progressive paralysis of the central nervous system as alcohol, commencing with the highest cerebral functions, those of self-control, and passing downward through the lower intracranial divisions. The spinal cord is affected before the medullary centres, which are the last part of the central nervous system to become paralyzed. As in the case of alcohol, it is at first difficult to believe that the excitement of anæsthesia is due to the suppression of the self-control only, but the wild movements are often aroused by the sense of restraint and opposition when the mind is unable to appreciate the necessity for these measures. The depression of the motor areas has been shown experimentally in the case of chloroform and ether, a much stronger electric stimulus being necessary to produce movement of a limb after these drugs than before them; their excitability by the electric current has not been tested, however, during the excitement stage. The electrical current of action disappears in surgical anæsthesia and with it the conduction of nerve impulses from nerve cell to nerve cell (Forbes).

The anæsthesia is not produced equally rapidly throughout the body, the back and the extremities first becoming insensible, then the genital organs and rectum and last of all, the parts supplied by the trigeminus. The reflexes of the spinal cord are depressed by small quantities of ether or chloroform and are finally paralyzed completely; sometimes ether increases the reflexes for a short period (Leeuwen). The character of the reflex is changed, for Sherrington finds that stimulation of an afferent nerve which normally causes a reflex contraction, may under chloroform be followed by inhibition. A similar reversal has been described in the medulla oblongata by Bayliss.

Both of the anæsthetics affect the sensory functions before the motor, as is shown by movements occurring long after all sensation has disappeared. And Bernstein found in some cases that if chloroform was excluded from an area of the spinal cord by destruction of part of the pia mater, reflexes could be elicited in other parts of the cord by the irritation of sensory nerves whose cells lay in the protected area, while irritation of nerves, the cells of which were exposed to the chloroform, had no effect (Fig. 6). In the protected area there were, of course, both motor and sensory cells, and an impulse reaching the protected sensory cell was transmitted to the neighboring and also to more distant motor cells. An impulse reaching the

exposed sensory cell, on the other hand, was not transmitted to the motor cells, although these were shown by the first part of the experiment to be capable of stimulation. This experiment is best interpreted by supposing that the anæsthetics act first on the first synapse in the cord that is met by an afferent impulse. Later, however, the motor cells or their synapses are also paralyzed, as is shown by stimulation of the cord having no effect, even when the respiration is still active.

Electrical stimulation of the cerebral motor areas produces movement for sometime after sensation has been lost, but as the anæsthesia becomes deeper, their irritability disappears. Finally the medullary centres are also paralyzed by the anæsthetic. There is some evidence that they

Fig. 6

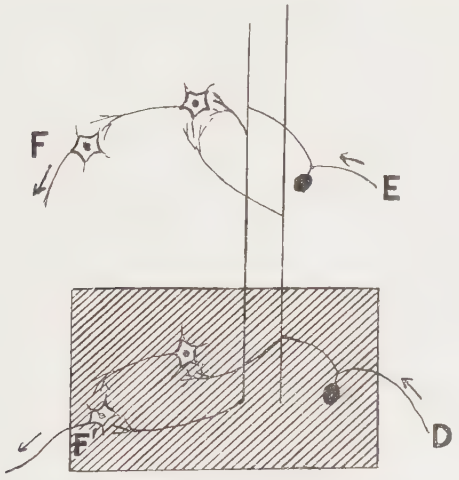


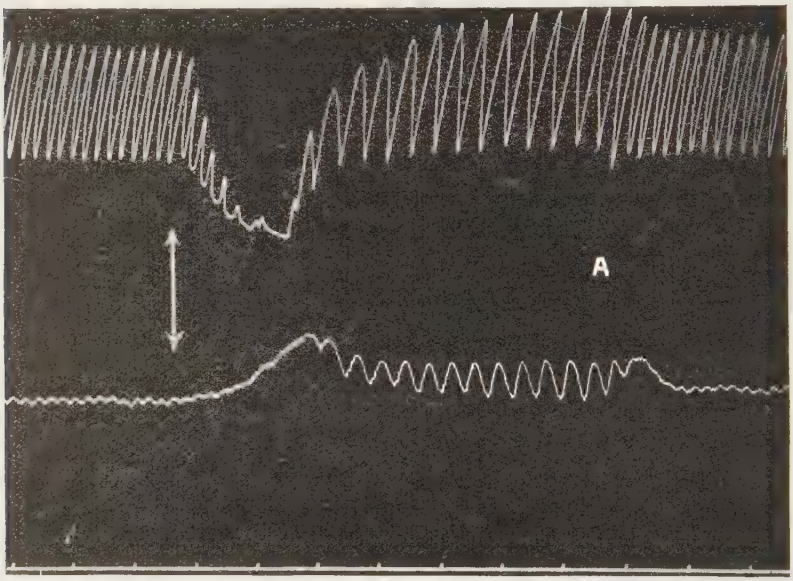
Diagram of Bernstein's experiment on the spinal cord; the part exposed to chloroform is represented by the shaded, while the rest is protected and normal. A sensory impression traveling by the posterior root fibre *D* does not elicit a reflex movement, but one reaching the cord through the unaffected root *E* causes reflex impulses, which may be sent out by the motor cell *F* in the unaffected area, or by *F'* in the poisoned area. The cells of the anterior horns, *F'* and the dendrites surrounding them are, therefore, intact after the reflex arc is interrupted at some other point.

are first stimulated directly by chloroform and ether (page 208). The medullary centres are liable to be affected by reflex stimulation up to the moment at which they cease to send out impulses, for the respiratory centre responds to stimulation of the superior laryngeal nerve as long as the respiration continues. It is possible that the motor cells are not directly paralyzed by the drug, but can only send out impulses received from the sensory cells, and that the paralysis of these is the cause of the asphyxia.

Shortly stated, the direct action of chloroform and ether on the central nervous system is a descending depression and paralysis which affects the medullary centres last of all, and which involves the synapses on the sensory and receptive tracts sooner than the motor neurons.

The action of chloroform and ether on the **Respiratory Centre** is partly direct and partly indirect. In the first stage, the respiratory movements may be slowed or stopped temporarily by a reflex action set up by the irritation of the terminations of the trigeminus in the nose and throat and of the pneumogastric in the larynx and bronchi, but this interruption is only of short duration and may be induced by any irritant applied to the respiratory passages (Fig. 7). During the second stage the respiration is often rendered irregular by the convulsive struggling, which produces alternately periods of asphyxia and deep gasping movements. There is further some evidence that the respiratory

FIG. 7



Tracings of the respiration (upper) and blood-pressure (lower) of a rabbit at the beginning of ether inhalation, which is indicated by the arrow. The respiration immediately becomes very shallow, and then after a pause becomes slow and deep (reflex inhibition). The blood-pressure rises and the pulse is slowed by reflexes acting on the vasomotor and vagus centres. The normal condition is restored at once when the ether is removed from the nose at *A*.

centre is rendered more irritable by low concentrations of the anæsthetics, more especially by ether. During the third stage, the respiration is regular and no reflex disturbance occurs, because the sensibility is so dulled that the continued irritation of the nerve ends causes no reflex response. In this stage the breathing is slow and shallow, mainly because the ordinary movements of the body are suppressed and thus less carbonic acid is carried to the centre, that is, the normal stimulus of the respiratory centre is diminished; partly, because the centre is reduced in excitability by the direct action of the anæsthetic. If the drug be pushed, the weakness and slowness of the movements increase,

until the respiration ceases entirely from paralysis of the centre; in addition to its direct action on the centre, chloroform affects the respiration in deep anæsthesia by inducing anæmia of the medulla through its effects on the circulation.

The effects of the anæsthetics on the **Circulation** are extremely complicated, because the heart varies in its reaction in different cases and under different anæsthetics, and in addition the changes in the respiration and the stage of excitement add to the difficulty of the subject. The changes observed in the pulse in man have already been described (p. 205). The blood-pressure in man has been found to be reduced by chloroform even in the earlier stages, and in deep anæsthesia the fall may be very marked. Under ether the pressure rises slightly in the first and second stages, partly from the reflexes arising from the local irritation, partly from the muscular movements, and partly perhaps from stimulation of the vasomotor centre. During complete anæsthesia from ether it falls again to slightly above the normal or a few millimeters below it, but never reaches a point indicating grave circulatory disturbance (Blauel, Cook and Briggs).

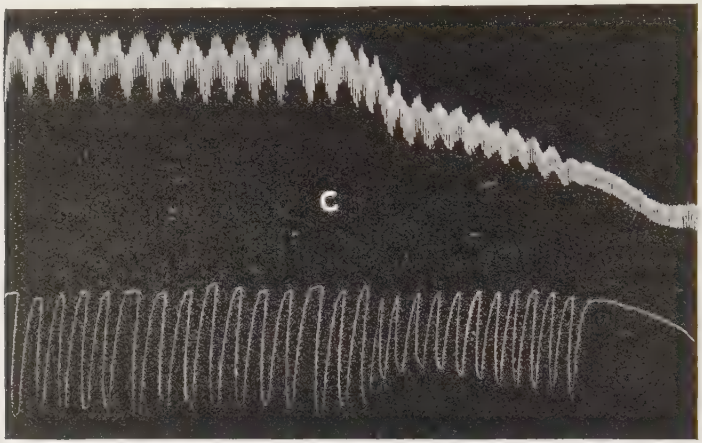
In animals, the first change in the blood-pressure is often a slowing or even standstill of the heart from the irritation of the air passages stimulating the inhibitory centre reflexly. The blood-pressure may thus fall abruptly, but in other instances the inhibition of the heart may be compensated by vasoconstriction from reflex stimulation of the vasomotor centre, so that the blood-pressure may rise while the heart is slowed (Fig. 7). Later, the blood-pressure falls slightly in chloroform anæsthesia, but strong vapor causes a marked and dangerous fall. The heart survives after the respiration fails in most experiments but the blood-pressure is very distinctly lower at this time (Fig. 8). Under ether the blood-pressure often is slightly lower, but it remains much higher than under chloroform when the respiration fails (Fig. 9). The cause of the fall in blood-pressure under chloroform has been much disputed, but is now generally ascribed to the action on the heart. Ether being less poisonous to the heart has a correspondingly slight action on the blood-pressure.

Heart.—The frog's heart under chloroform or ether beats more slowly and more weakly, and at the same time undergoes a certain amount of dilatation, all owing to the paralyzing effects of these drugs on the cardiac muscle.

The effects on the mammalian heart under chloroform are very similar. The slowing is not so marked, however, as the weakness and the dilatation, so that the rhythm of the pulse does not indicate the extent to which the heart is affected. The auricles are weakened by smaller quantities than the ventricles, which relax more completely in diastole, however (Fig. 10). The diminution in the strength of the auricles progresses rapidly, while the ventricular dilatation soon reaches a maximum and is accompanied by lessened force of contraction. The auricular weakness soon becomes so great that practically no blood is expelled by its systole, and the slowing of the heart, which has not been

very marked up to this point, becomes distinct. The ventricular contractions next become extremely weak and occasionally fail entirely,

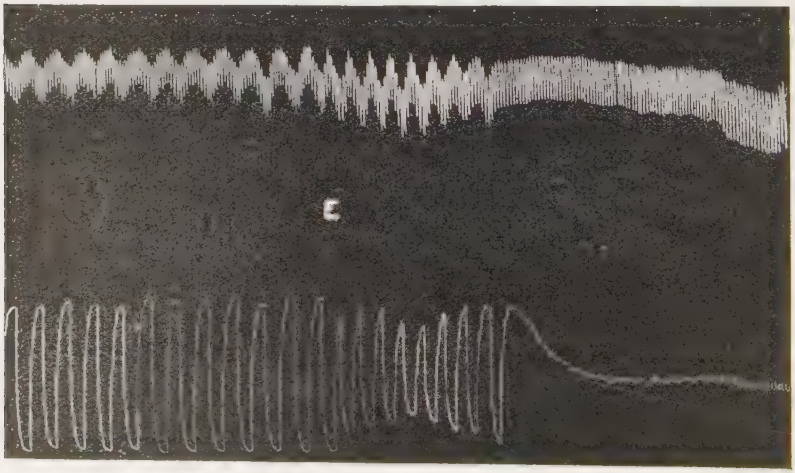
Fig. 8



The respiration (lower tracing) and blood-pressure (upper tracing) in chloroform anæsthesia in a cat. At *C* strong vapor was inhaled and a rapid fall in the blood-pressure began. The respiration ceased, the heart continuing to beat for some time. (Contrast Fig. 9.)

and soon afterward the heart comes to a standstill in diastole. In its weakened state, the heart can be inhibited more easily than usual,

Fig. 9



Respiration (lower tracing) and blood-pressure (upper tracing) of a cat under ether. At *E* strong vapor was inhaled and soon afterward the respiration ceased, while the blood-pressure remained high for some time afterwards. (Contrast blood-pressure in Fig. 8.)

and vagus stimulation may arrest it finally, the contractions not returning after the stimulation ceases (Embley).

When ether is inhaled in high concentrations the changes in the heart resemble those under chloroform, but it is difficult to elicit the extreme weakness and the standstill unless asphyxia is present also.

The relative toxicity of chloroform and ether in the heart has been examined by perfusing their solutions in Ringer's solution through the coronary vessels; 0.001 per cent. of chloroform had a distinctly deleterious action and 0.015 was sufficient to arrest it, while 0.4 per cent. of ether was required to stop the heart perfused in the same way. This indicates that chloroform is 25–30 times as poisonous to the mammalian heart as ether; the same proportion has been found in cold-blooded animals and in mammalian hearts perfused with blood (Schram, Leeuwen and Made). The chloroform contained in the blood during anæsthesia is sufficient to injure the heart, while when ether is inhaled in a concentration leading to arrest of the respiration, this does not damage the heart muscle.

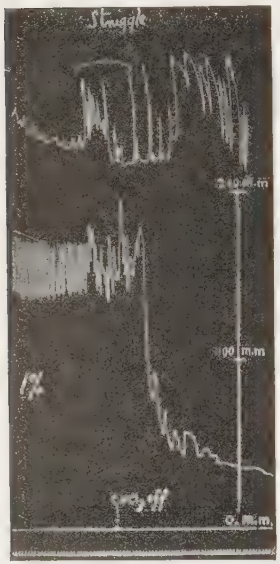
Fig. 10

Myocardiographic record of the movements of the right auricle (upper tracing) and right ventricle (lower tracing) of the dog during the inhalation of concentrated chloroform vapor. During systole the lever attached to the auricle moves from D' to S', that attached to the ventricle from D to S. In diastole they return to D' and D respectively. At A, concentrated chloroform was inhaled The excursion of the levers toward systole rapidly diminished, while that of the ventricle towards D was somewhat augmented. After a short time the auricle ceased in diastole, while the ventricle continued to beat, though much weakened. At B, the chloroform was shut off and the heart began to recover very soon afterward.

Vessels.—It has been shown experimentally that the vasomotor centre is depressed by chloroform, though this is sometimes masked by its responding by increased activity to the weakness of the heart or to partial asphyxia (Pilcher and Sollmann); the direct action on the centre is of little importance. In the later stages the vasoconstrictor centre undergoes some obscure change, so that sensory impulses which normally excite it and cause constriction of the vessels, now inhibit it and cause dilatation of the vessels (Bayliss). The vasodilator centre continues to respond in its normal way to sensory impulses. Ether seems to have little or no direct action on the vasoconstrictor centre, but the dilatation of the skin vessels indicates that it excites the vasodilator function directly or indirectly.

The direct action on the vessel walls seems to be of greater importance than that on the innervating centres. When chloroform circulates in the vessels in the concentrations used in anæsthesia it tends to relax them from a depressing effect on the muscle fibres; all the vessels are not equally affected, however, those of the splanchnic area dilating more readily than those of the limbs, which may even be constricted. Chloroform in higher concentration may tend to constrict also the mesenteric vessels, but this does not occur in the intact animal, in which such concentrations would prove immediately fatal to the heart.

Fig. 11



Tracing of the blood-pressure (lower) and of the respiration (upper) of a cat under chloroform; failure of the heart (ventricular fibrillation) immediately after violent struggling. The blood-pressure falls rapidly, while deep, gasping respiration continues for a short time and then ceases. (Levy.)

In practice, the low blood-pressure under chloroform is mainly due to the action on the heart; in less degree to the dilatation of the vessels in the abdomen.

Ether dilates the peripheral vessels like chloroform when it is perfused through them, and if it is inhaled in abundance of air this dilatation occurs in the living animal and may cause a fall in blood-pressure. This is often absent however, because the direct vascular action is opposed by the vasomotor centre which is excited by an insufficient air supply; for in ether anæsthesia there is very often present a partial asphyxia induced by the close approximation of the inhaler to the mouth and nose.

Syncope in Anæsthesia.—In a certain number of experiments the reaction of the circulation to chloroform is very different from the gradual depression described above. In these, the heart suddenly becomes irregular or ceases to beat abruptly, the blood-pressure falls to zero, and after a few gasping respirations all movements cease (Fig. 11). This sudden heart failure often occurs in the early stages of anæsthesia, or when the inhalation is irregular or has been suspended. Embley has explained it by inhibitory stimulation from which the weakened heart cannot recover. But Levy attributes it to the onset of ventricular fibrillation and has brought a large amount of evidence for his view. This fibrillation is often the culmination of a series of irregularities, such as extrasystoles and tachycardia, but may not be preceded by these in all cases. It indicates a condition of abnormal irritability of the heart under chloroform, and other experiments have given some evidence for a phase of increased excitability preceding the depression ordinarily observed. This form of cardiac failure is very often final, but in a small proportion of cases the heart resumes its normal contractions and the animal

recovers. Fibrillation is especially liable to occur from sensory nerve stimulation during light anæsthesia, and it is possible that here the excitatory effect on the heart is reinforced by reflexes through the accelerator apparatus or by an increased secretion of the suprarenal glands. It is not proved that the inhibitory nerves are involved in this form of heart failure, though there is some evidence in favor of this view.

Ether does not seem to have any such action on the heart, and fibrillation of the ventricle has not been observed under it. In fact, sudden circulatory failure under ether is a very rare occurrence, compared with chloroform. Henderson suggests that these rare fatalities under ether may be the result of a great reduction of the carbonic acid of the blood (acapnia), from excessive breathing during the excitement stage or during imperfect anæsthesia. Acapnia is known to act deleteriously on the heart, but further work is required before this view of the fatalities under ether can be regarded as established.

The **Muscles** and **Nerves** are not affected by chloroform when inhaled, a much higher concentration being required to act on the nerve fibre than on the nerve cell. When a frog's muscle is exposed to an atmosphere of either of them, it is weakened, loses its irritability and eventually passes into rigor mortis; the limb muscles in mammals are weakened when strong solutions (0.1–0.2 per cent.) are perfused through them, but are unaffected by concentrations which arrest the heart in a few minutes. Waller has shown that when a frog's nerve is exposed to chloroform or ether vapor in weak dilution, its irritability is at first increased; strong vapor, on the other hand, abolishes the excitability temporarily in the case of ether, generally permanently in that of chloroform, which is much the more powerful nerve poison of the two. The sensory fibres are said to be paralyzed sooner than the motor when chloroform or ether is applied to a mixed nerve (Pereles and Sachs), and some motor fibres of a trunk may remain unaffected, while others are paralyzed. The local paralyzing effects of ether have been elicited repeatedly in the human subject by its subcutaneous injection, and have occasionally been followed by neuritis and permanent weakness.

Chloroform and ether dissolve the **Red Corpuscles** and free the hæmoglobin when they are shaken with defibrinated blood outside the body, and chloroform is said to retard the reduction of oxyhæmoglobin by forming a loose combination with it; Da Costa holds that ether tends to destroy the red cells during anæsthesia, and advises caution in its administration in cases in which a diminution in their numbers may be of serious import. In the blood, chloroform is carried by the red cells for the most part, less than 10 per cent., being free in the plasma. It appears to form a loose combination or solution in the cholesterin and lecithin of the corpuscles. Ether is said to be more equally distributed between the corpuscles and plasma.

The amount of chloroform in the blood during the stage of anæsthesia is about 25–35 mgs. in 100 c.c. When the respiration fails the blood is found to contain 40–70 mg. per 100 c.c. (Buckmaster and Gardner). During the induction of anæsthesia the arterial blood contains more than the venous, part of the chloroform being taken up by the tissues as it passes through the capillaries. On the other hand, as the anæsthesia

passes off, the venous blood contains more than the arterial, the anæsthetic taken up from the tissues in the capillaries being eliminated in the lungs. Nicloux states that in light anæsthesia from ether the blood contains about 100–110 mgs. per 100 c.c., in deep anæsthesia 130–140 mgs., while 160–170 mgs. per 100 c.c. proves fatal from failure of the respiration. The margin of safety in anæsthesia is thus narrower than is generally recognized, for the concentration in the blood necessary for anæsthesia is about half that which is fatal.

The effects of chloroform and ether on the **Pupil** present some variation in different animals, and, indeed, are not very constant in man. No entirely satisfactory explanation of their mechanism has been offered as yet. The dilatation of the pupils in the first and second stages is merely the accompaniment of the general excitement and anxiety, and is not specific. The contraction in the stage of unconsciousness is similar to that seen in natural sleep, and is evidently of central origin. The dilatation occurring during wakening or vomiting is evidently caused by the same process as that of the preliminary stages. Just before death the pupil dilates, and this may perhaps be attributed to the effects of asphyxia on the muscle of the iris, and is so frequently observed in death from other causes that it cannot be regarded as a direct result of the chloroform.

The local effects of the anæsthetics on the **Alimentary Canal** and **Respiratory Passages** are confined to irritation with resultant reflexes. Thus the profuse secretion of saliva and mucus is due to the irritation causing increased activity of the glands reflexly, and can be arrested by atropine. It has been stated that the bronchial rhonchi are due entirely to aspirated saliva, but this is incorrect, as they occur in animals to which the anæsthetic has been given through a tracheal cannula. The irritation is much greater when concentrated ether fumes are inhaled than in ordinary chloroform anæsthesia.[1]

The vomiting which is so often a feature of anæsthesia may arise in part from the irritating action on the stomach of the chloroform or ether swallowed in the mucus, but is mainly of central origin, for vomiting also occurs when ether is injected intravenously in man and also under nitrous oxide anæsthesia in some cases; here the local irritation can only play a small part, and the medullary centre is probably involved directly, perhaps in the same way as occurs in shock and collapse. In the early stage vomiting sometimes occurs from the odor and taste of the anæsthetic, more especially in people who have been anæsthetized previously and have unpleasant associations with the odor. The ordinary movements of the stomach and intestine do not seem to be influenced by anæsthesia, unless when it is accompanied by asphyxia, when the peristalsis may be increased; but after very prolonged and deep anæsthesia in animals the stomach sometimes ceases its movement

[1] Dixon and Ransom have found that the inhalation of ether, chloroform or other volatile substances causes a contraction of the bronchial muscle, lasting about half a minute; it appears to be an accompaniment of the passage of the vapor into the muscle cell.

in a fully dilated position, and it is possible that some such local factor may be involved in the late vomiting after anæsthesia.

The **Kidney** appears to be affected in a certain proportion of cases of anæsthesia in man, as is shown by the appearance of albumin in the urine. Chloroform induces typical fatty degeneration occasionally, while albuminuria has been observed in a certain proportion of cases after ether. The proportion of cases in which this organ is affected seems to vary extraordinarily, some authorities finding albuminuria in 30 per cent. of the cases where chloroform was used; while others could detect it in less than 5 per cent. Kemp ascribes the renal effects of ether to vasoconstriction which arises from partial asphyxia from the inhaler being applied too closely; when asphyxiation is avoided, albuminuria is hardly met with under ether, and most surgeons consider chloroform far more deleterious to the kidney. The secretion of urine is generally diminished during anæsthesia with chloroform or ether, from the reduced blood-pressure and imperfect aëration of the blood; McNider finds that in the dog the damage to the kidney from the anæsthetics is much greater in old animals than in young ones and brings this into relation with the amount of stainable lipoid in the renal cells. After recovery from ether anæsthesia some diuresis may occur, or the urine may remain scanty for some hours.

The **Uterine Contractions** during parturition seem little influenced by moderate anæsthesia, but are somewhat slowed in the deeper stages. Chloroform and ether pass into the fœtal blood, and some experiments are recorded in which the fœtus was killed by the inhalation, while the mother recovered. This may be caused either by the direct action of the drug on the young animal, or by the low maternal blood-pressure leading to its asphyxia. It does not seem dangerous to induce a moderate degree of anæsthesia during labor in human beings, although here, too, the effects on the child are shown by an increase in the nitrogen excretion in the urine for some days; some authorities attribute many of the diseases of the first days of life to the use of chloroform during labor, but the evidence is not convincing.

The **Temperature** falls during anæsthesia of even short duration. Thus Kappeler found it reduced 0.2–1.1° C. when chloroform was inhaled 15–40 minutes, and a fall of 3–5° C. has been observed during very long anæsthesia. This action is due partly to the greater output of heat through the dilated skin vessels, but mainly to lessened heat production from the diminished muscular movement; the production of CO_2 falls for the same reason, and doubtless the oxygen absorption. This is not evidence of direct action on the tissues, but is one of the consequences of the central nervous depression.

Of late years a good deal of interest has been manifested in the effects of the anæsthetics on the **Metabolism of the tissues**, and it is now generally recognized that chloroform, in addition to its action on the central nervous system, produces marked changes in the nutritive processes of protoplasm. The simpler organisms, which are devoid of nervous structure, are killed in comparatively dilute solutions, and

chloroform water, therefore, retards putrefaction, the fermentation of yeasts and the movements of cilia. It seems to hinder the action of some ferments, such as pepsin and rennet ferment, when added in comparatively large quantities, but increases their activity in greater dilution. Plants cease to assimilate carbonic acid, but are not killed by chloroform except in very large quantities. In the higher animals and in man, the processes of life and nutrition of the different organs also undergo alteration, quite apart from the effects on the nervous system. Thus fatty infiltration of various organs is produced by chloroform administered repeatedly and even by a single inhalation in some cases. The organs implicated in this change are the liver, heart and kidneys more especially, but degeneration of ordinary muscle has also been observed occasionally. If this process attains a certain degree of development, it may lead to failure of the heart, but otherwise the tissues recover in the course of a few days. Traces of fatty infiltration have been observed after prolonged ether narcosis also, but they are so slight that no significance attaches to them from a practical point of view (Selbach). Given in small quantities for several months, chloroform leads to atrophic cirrhosis of the liver, and, to a less extent, of the kidneys, spleen and lungs, this cirrhotic change forming a sequel to preliminary fatty changes of the parenchymatous cells. In young adults chloroform has occasionally given rise to a form of liver affection which closely resembles acute yellow atrophy. In these cases after recovery from the anæsthetic, the patient becomes restless and uneasy and in a few hours delirium and coma may appear. Jaundice, cutaneous hæmorrhages (from a diminished amount of fibrinogen in the blood), tenderness over the liver suggest an affection of this organ, and in fatal cases it is found to present the same appearance as in acute yellow atrophy, the cells in the centre of the lobules having undergone necrosis; chemical examination proves that an acute autolytic destruction of the organ has occurred (Wells). In animals this necrosis is less liable to occur if the diet previously has been rich in carbohydrates, while fats seem to predispose to it.

The effects of chloroform on the nutrition of the tissues are shown in the urine secreted during and after anæsthesia, though they are more marked when the drug is swallowed, from its being more slowly absorbed and thus acting for a longer time. The nitrogen eliminated is considerably increased, and the unoxidized sulphur shows a similar augmentation, and these would seem to indicate an increased protein destruction and a disturbance of the oxidation in the tissues; another observation pointing in the same direction is the appearance of creatin in the urine and the reduced excretion of creatinin.

The carbohydrate metabolism is also impaired, for acetone and sugar are often present in the urine after chloroform, and it has long been known that diabetes is liable to be aggravated by this anæsthetic and may prove fatal. The sugar of the blood is increased and the glycogen of the liver diminished or absent, from a specific action on the liver cells (Paton).

Bile pigment is said to occur in the urine in a considerable number of cases of anæsthesia with chloroform, especially one or two days after the administration. The chlorides and the acidity of the urine are augmented and this has sometimes been regarded as evidence that chloroform is decomposed in the tissues, but the chlorides are also increased by ether though not in the same degree.

These effects of chloroform on the metabolism resemble very closely those of phosphorus poisoning, and have, like them, been ascribed to autolysis and the formation of acid in excess in the tissues; this acid may be furnished in part by the decomposition of chloroform, with the formation of hydrochloric acid. They seem to occur only after those substances of the fatty series in which chlorine is substituted, ether having little or no effect in producing fatty degeneration or in changing the proportion of the sulphur compounds in the urine. An excess of sugar is found in the blood after ether anæsthesia in dogs and leads to glycosuria; this may arise from excessive activity of the suprarenal bodies during the excitement or during partial asphyxia, and not from any direct action of the ether on the metabolism (Hawk). In light anæsthesia from ether, the available alkali of the blood is slightly reduced and the hydrogen-ion concentration rises, and this becomes more marked as the anæsthesia becomes deeper; the blood loses some of its plasma, the CO_2 tension rises and the oxygen first rises and then falls. Some of the carbonate is replaced by some unknown acid (Van Slyke).

Immunity.—Anæsthesia with chloroform or ether reduces the resistance of the tissues and renders animals more susceptible to the invasion of bacteria and to the action of toxins.

Distribution in the Body.—When chloroform or ether vapor is inhaled, it passes rapidly into the blood by diffusion and is distributed throughout the body, mainly by the blood cells in the case of chloroform, while the plasma carries a considerable amount of ether. The anæsthetic immediately begins to leave the blood for the tissues and appears to be taken up especially by the central nervous system, in which it is found in larger quantities than in the muscles, liver, or blood. This unequal distribution probably arises from the greater amount of lipoid substances in the central nervous system, which dissolve the chloroform and ether and retain them. This flow from the pulmonary alveoli to the blood and thence to the tissues lasts until the vapor tension is the same in each, and the amount in the brain is thus determined by that in the blood, which again depends on that in the alveoli. If the inhalation ceases, the tension in the lungs falls and a backward flow follows from the blood into the air and from the brain into the blood.

The **Excretion** of both ether and chloroform takes place mainly by the lungs. Most of the anæsthetic is eliminated very rapidly, but traces of chloroform are said to be found in the breath for twenty-four hours after the inhalation and even longer in cases in which there is a tenacious mucous secretion from the bronchi. As far as is known this is the only way in which ether is excreted, but small quantities of chloro-

form escape by other channels, for it has been found in the urine, and is said to occur in the perspiration and the milk.[1]

Differences Between Chloroform and Ether.—Ether and chloroform resemble each other closely in their general effects, but differ in power and in other points of importance. Their relative strength as anæsthetics is shown by a comparison of the vapor concentration of each in a hundred volumes of air required to induce anæsthesia.[2]

Chloroform.	Ether.	
0.5–0.7	1.5–2.5	Insufficient to cause anæsthesia.
1.0	3–3.5	Causes anæsthesia on prolonged inhalation.
2.0	6.0	Arrests respiration after ten to fifteen minutes.

The amount of anæsthetic in 100 c.c of the blood shows the same proportion.

Chloroform.	Ether.	
25–35 mgs.	100–140 mgs.	Anæsthesia.
40–70 mgs.	160–170 mgs.	Respiratory arrest.

The depressant effect of chloroform on the brain is thus 3–3½ times as great as that of ether, and its power to arrest respiration is about three times as great. The depressant action on the heart of chloroform is about 25 30 times that of ether, and the extremely dangerous cardiac syncope which is seen under chloroform is unknown under ether. Ether has to be given in more concentrated form to produce anæsthesia, and, therefore, produces more irritation of the air passages, as shown by the greater secretion of saliva and mucus, by coughing, and by the sensation of asphyxia. Anæsthesia is produced with greater difficulty, more slowly and often less perfectly than with chloroform, and the stage of excitement is generally more violent and prolonged. But the pulse is not nearly so much affected as by chloroform; it may be somewhat slower than usual, but is full and strong. The concentration of chloroform which is necessary to produce anæsthesia is very close to the concentration which causes serious impairment of the heart's action, while, on the other hand, 3½ per cent. ether vapor is sufficient to maintain narcosis, but a very much stronger concentration is required to cause a dangerous condition of the heart. In the same way, the difference in the concentration required to produce anæsthesia and that which will stop the respiration is smaller in chloroform than in ether, and the anæsthetist has thus more leeway when he uses the latter. The changes in the metabolism following the use of chloroform are not produced to the same extent, if at all, by ether.

Regarding the **Choice of an Anæsthetic**, it must be said that each has its advantages, but that ether is less liable to cause dangerous symptoms than chloroform, and ought, therefore, to be used wherever special

[1] The statement that some carbon monoxide is formed in the tissues from the oxidation of chloroform is erroneous.

[2] Boothby finds a much higher percentage of ether necessary than any other author; thus he recommends a vapor of about 13 per cent. of ether by volume to induce anæsthesia and one of 6 per cent. to maintain it. Others have found this percentage fatal within a short time.

circumstances do not indicate the latter. Chloroform is always preferred by the patient, for it causes less irritation and less feeling of suffocation, and it is often preferred by the surgeon because it induces anæsthesia sooner and less of it is required. In cases where excitement is to be avoided as much as possible, or in which very deep anæsthesia with complete muscular relaxation is required, and in irritable conditions of the air passages, chloroform ought to be used rather than ether. In drunkards, ether sometimes fails to induce deep anæsthesia, and in very hot climates anæsthesia with ether may be difficult and unpleasant to induce owing to its rapid evaporation, so that in these cases chloroform may be necessary. Lastly, where artificial lights are necessary (except the electric incandescent), or where the actual cautery is to be used, ether is dangerous on account of its inflammability, and chloroform is indicated. On the other hand, chloroform is specially contra-indicated in cases of fatty change of the heart and in renal disease. The disadvantages of both anæsthetics may often be avoided by inducing unconsciousness by chloroform and prolonging it by small quantities of ether. The effects of the prolonged use of chloroform are avoided in this way, and at the same time the excitement is less marked, and less irritation of the air passages is elicited than if the anæsthesia had been induced by concentrated ether vapor.

The **Dangers of Anæsthesia** are caused only in part by the direct action of the ether or chloroform, for fatal accidents have occurred from objects such as false teeth or tobacco plugs falling into the air passages and causing asphyxia, while vomited matter has been drawn into the larynx in some cases. Very often the relaxation of its muscles permits the tongue to fall back into the throat, rendering the breathing labored and stertorous; this is at once relieved when the tongue is drawn forward. The accumulation of saliva and mucus or blood in the throat may lead to similar symptoms. In these accidents the chloroform or ether is only indirectly the cause, but in a large and ever-increasing number of cases, the fatal effects must be ascribed to the direct action of the anæsthetics. The proportion of accidents during anæsthesia is very difficult to estimate, and great discrepancies occur in the statistics of different surgeons. Thus, in one of the London hospitals, one death occurred from chloroform in 1236 cases of anæsthesia; Juillard gives one in 3258, McGuire one in 15,000, as the proportion of fatalities, while Lawrie gives a series of over 40,000 cases without a single death. A fair average would seem to be one death in 3000 chloroform inhalations. The statistics of ether fatalities also vary from one death in 3000 to one in 16,000 cases, but probably one in 10,000-12,000 cases would represent the average mortality.[1]

The **Cause of Death** in anæsthesia has been a subject of discussion for over fifty years, and it is only now being recognized that there are at least two different forms of fatality which may occur. The first of these may be termed *Cardiac Syncope*, and occurs chiefly in chloro-

[1] Gurlt's careful statistics of 330,000 cases of anæsthesia gave a mortality of 1 in 2000 for chloroform and 1 in 5000 for ether, but these both seem unusually high.

form anæsthesia, to which it contributes the greater part of the fatalities. In these cases it is generally stated that the pulse suddenly disappears, the patient's face assumes a death-like pallor, the reflexes fail and the pupils dilate. The breathing suddenly becomes deep and labored (this often being the first symptom observed) and ceases after a short time. This accident is generally stated to occur in the early stages of anæsthesia, often before the operation has begun, but it is also met with after vomiting and other interruptions to a smooth course of anæsthesia. No explanation of the fatality was given until Embley's and Levy's researches on animals showed that a similar sudden heart failure may be observed experimentally. Embley regards these accidents as the result of excessive and abnormal inhibitory activity, and it is not impossible that the inhibitory apparatus may be involved in some of them. But Levy's explanation (p. 212) that the ventricle passes into fibrillation is more satisfactory and more in accordance with the clinical observations. The conditions which favor the onset of this condition are still obscure. Imperfect anæsthesia is obviously one of them, but this may conduce to the fibrillation either through permitting reflexes to act on the heart, or by subjecting it to the influence of a concentration of it adrenaline sufficient to induce it. Fibrillation has not been shown to occur under ether, and sudden cardiac syncope is a very rare occurrence under it and has not been investigated except by Henderson, whose views have been given already (p. 213).

A second form of accident in anæsthesia may be termed that from *Overdosage* and is less likely to be fatal. In this form the respiration becomes shallower and finally ceases while the pulse can still be felt, or the heart beat can still be felt or heard. The interval between the failure of the breathing and that of the pulse varies in different accounts and in some both are said to have disappeared simultaneously. But in these cases the gasping respiration is not seen, which is characteristic of the cardiac syncope. This accident occurs more especially when the anæsthetic has been pushed, or after prolonged inhalation. It may occur under chloroform or ether, and the majority of fatalities under the latter appear to be of this character, while the great bulk of chloroform deaths are due to cardiac syncope. This death from overdosage is easily elicited in animals (Figs. 8 and 9), and has been the subject of a large amount of experimental investigation, which has been directed chiefly to the question whether the respiration or the heart is the first to fail. This appears to depend on the concentration of the anæsthetic. If dilute chloroform or ether be inhaled, the respiration always ceases several minutes before the heart, which continues to beat fairly strongly at first but rapidly becomes weaker. If more concentrated vapor be used, the respiration again ceases before the heart, which is, however, much weakened and comes to a standstill after a short interval; and as the concentration is increased, the weakness of the heart, at the moment when the respiration fails, also increases, and the interval between the arrest of the respiration and that of the heart-beat becomes shorter. Finally, when air saturated

with vapor is inhaled, the interval between the two is so short as to be inappreciable (Fig. 12). When concentrated vapor of either chloroform or ether is inhaled, the pulse may be so weak as to be no longer perceptible before the respiration ceases, and the anæsthetist, therefore, believes that heart failure has been the cause of death, but if the movements of the heart be registered directly, it is found beating as long as the respiratory movements are carried on. The importance of the condition of the heart is further shown by the results of attempts to resuscitate the animal after the respiration has ceased; for if artificial respiration be commenced at once, the animal can invariably be restored to life, provided the heart has not been weakened too much; but if concentrated vapors have been inhaled, the heart is unable to carry on the circulation, and the animal cannot be resuscitated.

Fig. 12

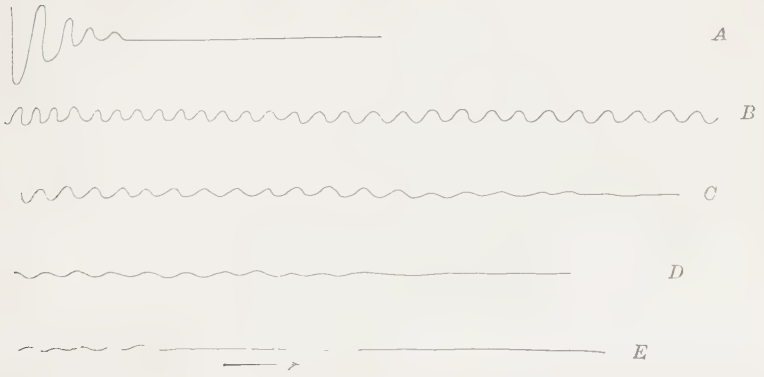


Diagram representing the state of the heart at the failure of respiration from an anæsthetic (chloroform or ether). *A* represents the respiratory movements, which cease very early in the tracing, *B*, the pulsations of the heart at this point if the anæsthetic vapor has been much diluted with air, *C* if it is of medium strength, *D* if very concentrated, and *E* if saturated. The heart pulsations are recorded by the mercury manometer.

Hill has pointed out that the failure of the respiration may be caused in part by the anæmia of the central nervous system from the fall in blood-pressure. The weakness of the heart induced by chloroform is therefore fraught with double danger, for not only is the circulation imperilled by it but the respiration is indirectly weakened.

From a practical point of view, it is of comparatively little importance whether there are a few fluttering beats of the heart after the last inspiration or not. The all-important question is whether the heart has been so injured as to be unable to carry on the circulation, and this is decided by the concentration of the vapor that has been inhaled. Even when dilute vapor of chloroform is inhaled, the heart is considerably injured when the respiration ceases, while under ether, unless very concentrated fumes be inhaled the weakness of the heart is much less.

The autopsy in cases of death by chloroform or ether shows no specific lesions. The blood is often dark colored from the asphyxia, and the heart is found dilated. Irritation of the respiratory passages may be present in ether poisoning, and the odor of the anæsthetic may be recognized in the different organs. Microscopic examination may show some alterations in the cells of the respiratory centre and cardiac ganglia, fragmentation of the heart muscle, and some degeneration of the liver, kidneys, spleen and heart after chloroform (Poroschin).

Late Deaths.—A good deal of interest has been excited by the discovery that the perils of anæsthesia are not over when consciousness returns, but that fatal consequences may follow several days later. These late fatalities are due to fatty changes of the heart, liver and kidneys or to diabetic coma in the case of chloroform, to bronchitis, pulmonary œdema and pneumonia after ether. No reliable data are as yet available as to the frequency of these sequelæ, as it is very difficult to distinguish between the results of the anæsthetic and the ordinary forms of disease. Even the proportion of cases in which albuminuria occurs after chloroform seems to vary remarkably in different hospitals, for it is given as low as 5 per cent. by some authors and as high as 30 per cent. by others; this may perhaps be explained by differences in the duration of the anæsthesia. The irritant effects of ether and the liability to pulmonary affections afterward have been so evident that some surgeons have returned to the use of chloroform, believing that the late effects in ether claim as high a proportion of victims as the more immediate effects of chloroform. This irritant action of ether may be avoided to some extent by allowing the vapor to be inhaled in a more dilute form than is often used in inducing anæsthesia. And there is reason to believe that the pulmonary effects are often intensified by the air inhaled being chilled by the evaporation of the ether, and that they may be lessened if this is avoided by suitable inhalers.

Apparatus and Principles.—The principles on which the safe production of anæsthesia is based, then, are comparatively simple, but their interpretation into practice has given rise to various methods. A large number of inhalers have been introduced with the object of permitting of only a certain degree of concentration of the vapors. But the great majority of these are entirely erroneous in principle, the concentration of the vapor being determined by the character of the respiration of the patient, and the number of accidents has not been appreciably reduced by their use. In one of these the amount of oxygen available for respiration was found to be reduced to 5 per cent., while the carbonic acid had risen to 7.8 per cent. after two minutes' respiration. This mixture of gases is insufficient to support the combustion of a candle, and is very near that which is immediately fatal to animal life. In another the concentration of the vapor was found to vary between 1.2 and 16.4 volumes per cent. Several apparatus have recently been constructed on correct principles, which allow of an exact gradation in the strength of the vapor inhaled, but

they are exceedingly cumbrous, and while they might be used in hospitals, are certainly not available for ordinary practice.

The advantage of this principle of measuring the concentration of the vapors is further only relative, for it has been shown that vapors so dilute as to be absolutely safe do not induce anæsthesia within a reasonable time. Thus 1 per cent. chloroform seems to be practically safe, but no surgeon will wait $\frac{1}{2}$–$\frac{3}{4}$ hr. for the anæsthetist. To induce anæsthesia, therefore, vapors have to be used which would in time be fatal, and only after the reflexes disappear is it possible to reduce the concentration to the point of absolute safety. The responsibility of the anæsthetist is, therefore, lessened, but by no means entirely removed by these methods. In the vast majority of cases, however, much simpler apparatus is used, and the ordinary mask or towel on which the anæsthetic is poured is not responsible for a larger proportion of accidents than the more complicated forms of apparatus. When no inhaler is used, the anæsthetist attempts to regulate the concentration of the vapor according to the symptoms, and this can be done with complete success by watching the respiration closely. If the breathing be shallow, much less concentrated vapor is inhaled into the alveoli than if it be deep and gasping, for in ordinary respiration the air in the smaller bronchioles and alveoli is not exchanged directly with every respiration, but only by a process of diffusion from the larger air passages. The deeper the respiration, however, the further does the vapor penetrate and the lower the concentration needed to change the quantity in the blood. An experienced anæsthetist, by watching the respiration, raising the mask during deep breathing and replacing it when it becomes steady, can regulate with sufficient nicety the concentration of the anæsthetic in the alveoli and thereby the quantity in the blood. When anæsthesia has been attained, he of course reduces the concentration until the return of the reflexes indicates awakening consciousness, and even then applies much smaller quantities than were necessary at first.

This method of inducing anæsthesia requires the anæsthetist to watch only the respiration and the reflexes, and is that advised by Simpson and his followers (see Hyderabad Commission Report). A further safeguard has been sought for in the condition of the pulse, and this would seem the natural consequence of what has been stated above as to the importance of the condition of the heart. The pulse, however, is not very reliable as a guide in anæsthesia, for in the second stage, in which a certain number of fatalities occur, it is quickened by the excitement and may be irregular, and only gives indications of danger when it is too late to take measures to prevent it. In the third stage it may become gradually weaker, and thus indicate approaching danger, but if the respiration be watched the warning is given earlier. A large number of anæsthetists advise that the pulse and respiration both be watched, and this would seem to be the safest method, provided always that the anæsthetist does not depend on the pulse too much for indications of danger, and does not allow it to distract his attention from the more important indications given by the respiration.

Preliminary Examination.—Before anæsthesia, a careful examination should be made of the condition of the patient, and if there is great anxiety and excitement, a hypodermic injection of morphine may be given beforehand, or chloral may be prescribed, but these are rarely necessary. Valvular disease of the heart does not contra-indicate an anæsthetic unless there are marked symptoms of inefficiency, such as dropsy or œdema. In fatty disease of the heart, on the other hand, chloroform is to be avoided, and if it seems extensive, ether is also dangerous from the strain put on the circulation during the excitement. Chloroform is liable to induce fatty degeneration of the heart, and for this reason it would not seem advisable to use it in successive operations on the same patient. Atheromatous arteries are dangerous from the tendency to apoplexy during the second stage also, and if anæsthesia is absolutely necessary, an opiate ought to be given previously. Anæsthesia is said to be dangerous in cases of brain tumor, and this may possibly arise from the fragility of the vessels; it is also induced with great care, if at all, in severe shock, in which the circulation is already in a dangerous state from the accumulation of the blood in the capillaries. In cases of bronchitis and catarrh of the air passages, chloroform is to be preferred to ether as it is less irritating, while in Bright's disease chloroform is generally more injurious than ether from the resultant albuminuria and tendency to fatty degeneration, although ether is also believed by many to disturb the renal functions. Advanced diabetes contra-indicates anæsthesia, the sugar increasing in the urine afterwards and coma and death sometimes supervening in the course of a few days. Da Costa recommends that where there are symptoms of anæmia, an examination of the blood should be made before anæsthesia, and states that where the hæmoglobin is found to be deficient, great care is necessary and that where it is lower than 50 per cent. of the normal, an anæsthetic is contra-indicated.

Practical Anæsthesia.—The patient should have a light, easily digested meal two to four hours before, so that the stomach may be empty and vomiting avoided as far as possible. The bowels should also be regulated the day before for the same reason. He should then be laid on a table of suitable height with a low pillow, and should remove false teeth and any other foreign object from the mouth. The clothing about the neck, chest and abdomen is to be loosened or removed to allow of perfectly free respiration, but warm blankets or warm bottles should be applied as far as possible to prevent the fall of temperature if the operation is likely to be a long one. The eyes are closed in order to protect the conjunctiva from the irritating vapor. The anæsthetic is then applied on a towel or on a mask, which ought to be freely permeable by the air, and ought not to fit closely to the face. Masks were formerly employed to administer ether (closed method) in which the respiration was seriously impeded, so that the patient was partially asphyxiated besides receiving a highly concentrated ether vapor. It must be remembered that the air passes through cloth with much greater difficulty when it is wet by the saliva and mucus, and that a

mask which is freely permeable at the commencement of an operation, may lead to asphyxia after it has been soaked during the first and second stages. The patient is instructed to breathe as regularly as possible, or to count from one upwards, and some of the anæsthetic is dropped on the mask. If the breath be held, the mask should be raised a little from the face, as the next inspiration will be a very deep one. During the excitement stage the respiration is irregular, and great care must be taken to avoid the inhalation of too concentrated vapor. As soon as the conjunctival reflex disappears, the mask is raised, and is replaced only when it reappears or when the patient evinces signs of pain. The object of the anæsthetist should be to maintain an even anæsthesia and to avoid sudden changes; this is best attained by raising and lowering the mask slightly, or by varying the number of drops of anæsthetic falling on it; the inhalation should not be completely interrupted except in danger. Throughout the anæsthesia care must be taken to prevent any interference with the respiration by the operator leaning on the thorax or abdomen. Very often stertorous respiration sets in from the tongue falling back into the throat, and this has to be remedied by pressing forward the angle of the jaw, or if this is not sufficient, by pulling out the tongue with a blunt-pointed forceps. Vomiting is a very common occurrence in anæsthesia, and when it sets in, the head is turned to one side and the vomited matter removed with a sponge.

A more serious accident is the failure of the respiration. A reflex arrest often occurs in the first stage, but is not of importance in itself, but only from the deep gasping inspiration which follows it. If the anæsthetic be given too long in concentrated form, however, the respiration fails from direct action on the centre, and this demands immediate attention. The head ought to be lowered at once, and the lower limbs elevated, in order to drive the blood to the head as far as possible and thus remedy the anæmia of the brain from the weakness of the heart that accompanies the cessation of the respiration. The epiglottis must be raised by pressing forward the angle of the jaw (Hare), or by dragging forward the base of the tongue with hook or finger. Artificial respiration in one or other form ought to be commenced at once, and carried on as long as is necessary; a large number of methods of performing artificial respiration have been proposed, but they can only be taught in a practical class and need not be entered upon here.[1] If the pulse is weak, intermittent pressure over the heart may aid it in carrying on the circulation, and in some cases the abdominal cavity has been rapidly opened and the heart compressed between one hand below the diaphragm and the other on the chest wall. This heroic measure has in some cases restored the heart beat and the respiration. Various drugs have been recommended in these cases, but it is exceedingly questionable whether they are really of service; alcohol, ammonia and ether have been injected subcutaneously, and may conceivably

[1] For a comparison of the efficacy of different forms see *Schäfer*, Medico-Chirurgical Transactions, vol. lxxxvi, supplement, 1904.

cause such local irritation as to reinstate the respiration reflexly, although this is improbable. Strychnine, caffeine and atropine have been injected as respiratory stimulants, and digitalis to strengthen the heart contraction; as a matter of fact, however, if the circulation is strong enough to cause the absorption of these drugs and carry them to the respiratory centre and the heart, the patient will recover with the artificial respiration alone, while on the other hand, they are of no value unless absorbed. Nitrite of amyl is useless, as it can only affect the heart by reducing the blood-pressure, which is already dangerously low. In animal experiments, the best results are obtained by the intravenous or intracardiac injection of adrenaline in saline solution.

Cardiac syncope and fibrillation is the most dangerous accident of anæsthesia, and probably is irremediable when fully developed. The treatment consists in inversion, artificial respiration, and massage of the heart. Embley recommends the injection of atropine, on the view that the condition is due to inhibition, and it might be thrown into the heart directly by means of a long hypodermic needle. The experiments of Levy show that adrenaline favors ventricular fibrillation under chloroform, and this powerful stimulant is therefore inadmissible in syncope.

In long operations, the attention of the anæsthetist should be directed to maintaining an even level of unconsciousness. When anæsthesia is reached it may be maintained by comparatively small quantities, and on the other hand owing to the fall of temperature and the prolonged action of the drug, the amount necessary to produce cessation of the respiration and the heart is much smaller than during shorter operations. In order to induce anæsthesia within a reasonable time, comparatively strong vapor may be used, but as soon as unconsciousness is reached, the vapor ought to be diluted as far as is compatible with the continuation of the narcosis.[1]

On the completion of the operation, the patient seldom requires further attention from the anæsthetist; after prolonged anæsthesia heat may be applied by warm bottles, etc., as the temperature often continues to fall for some time after the administration of the drug has ceased. If vomiting persists after the recovery of consciousness, ice may be sucked, or bismuth may be prescribed. The inhalation of vinegar has been recommended and relief is sometimes given by lavage of the stomach.

The patient should always be placed in the recumbent position when possible, as otherwise the weakened heart tends to drive the blood in the direction of least resistance, that is, downward, and in the depressed condition of the vasomotor centre, this is not counteracted by the contraction of the arterioles of the abdomen, and anæmia of the brain and fainting are liable to result. The operation ought

[1] In anæsthesia with measured percentages of chloroform, Alcock found it best to commence with vapor of 1 per cent., rising to 2 per cent. after two minutes and to 2½–3 per cent. in five minutes; this strength was continued until anæsthesia was attained, after which the concentration was reduced to 2 per cent. and further to 1 per cent. in the course of twenty minutes.

not to be commenced until anæsthesia is complete; otherwise reflex inhibition of the heart or syncope may result and lead to fatal results.

Various drugs have been advised as preliminaries to anæsthesia, generally with the object of preventing the reflex arrest of the respiration and heart. Thus atropine has been proposed to paralyze the vagus, and to arrest the mucous secretion and vomiting, and spraying of the nose with cocaine has recently been advised to paralyze the sensory terminations and so prevent the irritation which sets up the reflexes. It has been proposed to dilute ether or chloroform vapor with oxygen instead of air, but this has no advantages. In order to avoid the unpleasant suffocating effects of ether and to permit of less concentrated vapor being used, the injection of 0.01 G. ($\frac{1}{6}$ gr.) of morphine along with 0.5 mg. ($\frac{1}{120}$ gr.) of hyoscine has been advocated as a preliminary to ether anæsthesia, and this has become a routine procedure in some clinics, from which satisfactory results are recorded. In others, some less unpleasant anæsthetic, such as nitrous oxide or ethyl chloride, is used to induce anæsthesia, which is afterward maintained by ether.

Intravenous Infusion Anæsthesia.—The intravenous injection of ether has been advocated recently (Burkhardt), with the object of avoiding the local irritant effects of ether vapor in the lungs, and has proved useful, especially in operations on the mouth and throat, in which the anæsthetist is liable to be hampered by the surgeon. A solution of 5–8 per cent. of ether in sterilized Ringer's solution is slowly infused through a cannula introduced into a vein, and as anæsthesia is induced the rate of flow is lessened until the point is reached which is just sufficient to maintain unconsciousness. An injection of atropine is often given previously to lessen the mucous secretion of the bronchi, and morphine and hyoscine are also injected previously by some anæsthetists. The method has advantages in some conditions but is liable to cause hæmoglobinuria and is not adapted for ordinary surgical work, in which the inhalation method is simpler and involves less apparatus. Vomiting and marked mucous secretion occur from intravenous anæsthesia, the latter perhaps from the ether excretion through the lungs, which proceeds rapidly. Soporifics, such as hedonal, have been substituted for ether for infusion, but induce a very prolonged anæsthesia, which in some cases has proved fatal.

Various **Mixtures of the Anæsthetics** have been advised at different times. Of these the ACE mixture (alcohol 1, ether 2, and chloroform 3 parts by volume) is the best known. Its use has, however, been attended with numerous fatalities, as was only to be expected from a consideration of the volatility of the different ingredients. Ether, being the most volatile, is first inhaled, and then chloroform, and last of all the alcohol. The safe concentration of ether is, however, much greater than that of chloroform, and a vapor which may be perfectly safe as long as it consists of ether for the most part, may become exceedingly dangerous when it consists of chloroform. This method, therefore, increases the responsibility of the anæsthetist by leaving him in complete ignorance as to the composition of the anæsthetic at any given time. The same

criticism applies to a mixture of anæsthetics advocated by Schleich and containing ether, chloroform and petrol, which enjoyed a brief popularity some years ago.

The action of such mixtures is a simple sum of the actions of the constituents; the presence of chloroform does not intensify the anæsthetic action of ether, except in so far as the chloroform itself anæsthetizes. In other words there is no synergism between chloroform and ether.

Ethyl Chloride (C_2H_5Cl) has been advocated of recent years as an anæsthetic for minor operations and examinations, and possesses the advantages of acting very quickly and of leaving no after effects except occasionally some nausea, the patient generally feeling perfectly well in a few minutes. It is kept in sealed tubes and inhaled through a mask as it is extremely volatile, boiling at about 12° C. Anæsthesia is obtained in about two to five minutes, but complete muscular relaxation is often absent. Recovery follows a few minutes after the removal of the mask. It is not unpleasant to inhale and generally induces no excitement or other unfavorable symptoms. The pulse is generally slowed, while the respiration is deep. Embley states that in animals the effects are similar to those of chloroform, but that it is less poisonous to the heart, about nineteen times as concentrated vapor being necessary to weaken it. The concentration of ethyl chloride vapor necessary to induce cardiac inhibition is four times that of chloroform, and this inhibition is not fatal as the heart muscle is less affected. The vapor may be inhaled in 5–7 per cent. concentration without inducing inhibition in the dog. Nicloux found about 20 mgs. of ethyl chloride per 100 c.c. in the blood in light anæsthesia, from 30 to 150 mgs. in deep anæsthesia and 40–180 at death. A number of fatalities have occurred under its use, about one in three thousand of those anæsthetized. Some major operations have been performed under ethyl chloride, but it is found difficult to maintain a uniform anæsthesia, owing to the rapidity with which consciousness returns. It is often employed to introduce anæsthesia, which is then maintained with ether. Ethyl chloride should not be administered in larger quantities than 4–5 c.c.

Various other members of the fatty series have been introduced as general anæsthetics at different times, but few of them have proved to have any advantage over chloroform and ether, and fatalities have occurred after all of those that have received a wide trial. **Pental**, trimethylethylene ($(CH_3)_2C = CHCH_3$) was introduced for short operations but a number of accidents occurring under it led to its being abandoned. It produces anæsthesia before the reflexes disappear or the muscles relax, and not infrequently the jaws are tightly closed after consciousness is lost. In some cases tremor and convulsive attacks have occurred during its administration, but it seems to have very little action on the heart or circulation. **Ethyl Bromide** (C_2H_5Br) has also been used for short operations instead of chloroform, and produces anæsthesia with great rapidity. Consciousness returns quickly after the removal of the mask, but the inhalation is not so pleasant as that of ethyl chloride and patients complain of greater depression and discomfort afterward; several deaths have occurred from its use in dentistry, and this together with its tendency to decompose on keeping has led to its disuse. Ethylene bromide ($C_2H_4Br_2$) is a still more dangerous anæsthetic.

The other members of this series possess no practical importance. It may be mentioned that tetrachloride of carbon (CCl_4) differs from the others in causing convulsions, while perchlorethane (C_2Cl_6) is a crystalline solid and possesses too high a boiling point to be available for inhalation.

Therapeutic Uses.—Anæsthesia is generally induced for the purpose of surgical operations and examinations, and in labor. Until recent years, when it was necessary to perform an operation or manipulation involving much pain, the surgeon had to consider only which of the

two general anæsthetics was the better adapted to the case. But the improvements introduced in the methods of inducing local anæsthesia and the reintroduction of nitrous oxide and ethyl chloride as surgical anæsthetics have now enlarged his field of choice, and the further question has to be met whether unconsciousness is desirable, or whether the necessities of the case may not be met by paralyzing sensation at the seat of operation only. The advantages claimed for local anæsthesia will be discussed under cocaine, but the general conditions in which chloroform and ether are to be preferred may be stated shortly (see also nitrous oxide). General anæsthesia is absolutely essential where complete relaxation of the muscles is desired, and where the movements of the patient may imperil the success of the operation. Operations on the abdominal organs and around joints and such others as involve wide and deep incisions will almost certainly continue to be performed under chloroform or ether, although a few such operations have been performed under cocaine. In many less serious operations it is necessary also to have recourse to the older methods, which allow greater freedom to the surgeon, who is under no apprehension that he may reach a sensitive area and has thus one less source of anxiety than if the anæsthesia were localized. Another argument for the use of general anæsthetics is the effect which the anxiety and the sights and sounds of the operating room may have on a nervous patient even when no actual pain is felt. And a considerable amount of practice is required before complete local anæsthesia can be induced over an extensive field of operation, while the surgeon has often to interrupt his manipulations in order to admit of a fresh area being rendered analgesic. But there is no question that many operations in which ether or chloroform has hitherto been employed, will in the future be performed more often under local anæsthesia or nitrous oxide. In this class may be included most minor operations in which only very short or partial anæsthesia is necessary and in which no complications are to be anticipated. Nitrous oxide and ethyl chloride are scarcely to be regarded as rivals to ether and chloroform in any but minor operations. But in these they have the great advantage that the patient can be dismissed within a few minutes after the operation is completed, while if ether or chloroform is employed complete recovery is only reached after several hours; when the latter are used in minor operations, the discomfort resulting from the anæsthetic may be altogether out of proportion to the actual surgical manipulation.

During labor only the lighter degrees of anæsthesia are necessary, the object being to dull the pain without lessening to any marked extent the reflex irritability of the spinal cord, and accidents are extremely rare in this use of anæsthetics, although the common statement that they are unknown is incorrect. Some cases have been recorded in which it is believed that chloroform was fatal to the child and not to the mother, but it is, of course, impossible to state with certainty that the anæsthetic was the cause of death. If too deep anæsthesia is produced, however, it is quite conceivable that the labor

may be prolonged, or the blood-pressure so reduced as to lead to an imperfect exchange of gases in the placenta and thus to the death of the infant; or, as another explanation it might be suggested that the irritability of the respiratory centre of the child may be so reduced that it fails to react when the placental circulation is interrupted.

Anæsthetics are also employed in cases of extreme irritability of the central nervous system, as in strychnine poisoning, tetanus or other convulsive affections. In order to reduce these, it is unnecessary to produce deep anæsthesia, a few whiffs of chloroform being generally sufficient to produce quiet, often without affecting the consciousness to any marked extent. In cases of very acute pain, chloroform or ether may be used, but as a general rule morphine or opium is preferable, as the action lasts longer and the administration is more convenient. Immediate relief is given by the inhalation of a few drops of chloroform in some forms of asthma.

The local action of chloroform and ether on the stomach and skin is entirely independent of their action as anæsthetics, and has been discussed separately (see page 73).

Preparations.

U. S. P.—Chloroformum, a liquid containing 99–99.4 per cent. by weight of absolute chloroform ($CHCl_3$) and 0.6–1 per cent. of alcohol.

Æther, ether, a liquid composed of about 96 per cent. by weight of absolute ether or ethyl oxide ($(C_2H_5)_2O$) and about 4 per cent. of alcohol containing a little water.

Æthylis Chloridum, ethyl chloride (C_2H_5Cl), an extremely volatile liquid boiling at 12.5–13° C. (about 55° F.).

B. P.—Chloroformum, contains 98 per cent. of chloroform ($CHCl_3$), and 2 per cent. of absolute alcohol. Its specific gravity is 1.483–1.487

Æther Purificatus, ether, contains about 95 per cent. of absolute ether ($(C_2H_5)_2O$) along with some alcohol and water and has a specific gravity of 0.720.

Ethyl Chloridum, C_2H_5Cl, a very volatile liquid of specific gravity 0.92–0 96, and containing not less than 99.5 per cent. of ethyl chloride.

Chloroform is ordinarily formed by the action of chlorine on alcohol, the chlorine being added in the form of chlorinated lime. The crude drug is purified by repeated washing with water and sulphuric acid, and dried over calcium chloride. The fatalities following its use have frequently been ascribed to impurities, and a certain demand has arisen for a purer article than that required by the pharmacopœias. Another method of preparation has therefore been introduced, the decomposition of chloral by soda (*Chloroformum e Chloral præparatum*). Other pure forms are prepared from ordinary chloroform by crystallizing it by cold (Pictet), or by forming a compound with salicylid and decomposing it again by slight heat, *Chloroform* (*Anschutz*) or *Chloroform* (*Salicylid*).

The impurities of chloroform are due partly to imperfect manufacture and partly to decomposition. Along with the chloroform there distils over a small quantity of heavy, oily fluid, which may be isolated by Pictet's method, but whose composition is entirely unknown. DuBois-Reymond found that this fluid acted more strongly on the heart than pure chloroform, but it is very questionable whether the minute quantities inhaled in ordinary anæsthesia produce effects of any importance, and, on the other hand, it is quite certain that the use of absolutely pure chloroform does not prevent accidents Chloroform undergoes decomposition when exposed to light and air, hydrochloric acid and chlorine being set free in small quantity. These can affect

the course of anæsthesia only through their local irritant action, but if present in sufficient quantity may cause the respiration to be more irregular than usual in the earlier stages; the chloroform used for anæsthetic purposes ought, therefore, to be kept in a dark place or in colored bottles. Another decomposition occurs when chloroform is evaporated in the neighborhood of a large flame, such as that from gas or lamps, and hydrochloric acid and carbonylchloride or phosgene (CCl_2O) are formed; phosgene is one of the most dangerous gases known, for even one volume in 40,000 of air is sufficient to induce pulmonary œdema if inhaled for thirty minutes; the œdema comes on very slowly and proves fatal only after eight to twelve hours. Several accidents have occurred from this gas being formed in small operating rooms, both patient and attendants suffering from severe poisoning afterwards.

Chloroform is a heavy volatile fluid, of characteristic pleasant odor and hot, sweetish taste. Its specific gravity is 1.476 (U. S. P.) and 1.483–1.487 (B. P.), and it boils at 60–61° C. A number of tests are given for impurities, but those of importance can generally be detected by the odor, especially if some chloroform is allowed to evaporate in a watch-glass, when the last drop ought to have no irritant effect when inhaled. Chlorine and hydrochloric acid may be tested for by shaking the chloroform with distilled water, and testing the latter with potassium iodide and starch and with silver nitrate. The water ought to give no acid reaction to litmus. If left in contact with concentrated sulphuric acid, chloroform should not become darker within one hour, as this indicates the presence of some foreign unstable body. The other impurities require complicated chemical processes for their detection.

Ether is prepared by the action of sulphuric acid on alcohol, and is subsequently purified by washing with water and alkalies. It seldom contains impurities of importance. Æther purificatus (B. P.) or Æther (U. S. P.) is a very volatile fluid, of a suffocating, irritant odor and bitter taste. Its specific gravity is 0.716–0.717 (U. S. P.), and 0.720 (B. P.), and its boiling point is 35° C. It evaporates very rapidly in the air and should leave no foreign odor and no residue. When ether has been exposed to air and sunlight and to a varying temperature, it may contain acetaldehyde and peroxide bodies, which render it more irritant to the mucous membranes. It should not color litmus paper, nor be colored within an hour when shaken with potassium hydrate solution. Ether vapor is exceedingly inflammable when mixed with air, and it should therefore be kept in a cool place, away from gas flames or lamps.

Ethyl Chloride is obtained by the action of hydrochloric acid on alcohol, and is a gas at ordinary temperatures, but is supplied condensed into a colorless fluid with a pleasant odor. It is very volatile, inflammable and mobile, and is liable to contain traces of the same impurities as have been mentioned under chloroform. It should be kept in a cool place, away from lights or fire.

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3. Nitrous Oxide.

The oldest of the anæsthetics, nitrous oxide, N_2O, does not belong to the methane series, but may be discussed at this point.

Symptoms.—When a mixture of nitrous oxide and air is inhaled for a few seconds, a condition resembling alcoholic intoxication is produced, with much hilarity and laughter, so that the oxide is known popularly as "laughing gas."[1] Even at this point a certain amount of anæsthesia is obtained, and it was the observation that persons falling during this stage did not complain of pain that first suggested to Wells the anæsthetic properties of the gas. Davy had noted these forty years previously, but his suggestion that nitrous oxide might be used in surgical operations passed unnoticed.

The inhalation of a mixture of nitrous oxide, 4 parts, and oxygen, 1 part, causes after a few seconds a rushing, drumming, hammering in the ears, indistinct sight, and a feeling of warmth and comfort. The movements become exaggerated and uncertain, the gait is staggering, and the body sways from side to side. The patient seems brighter and more lively, and often bursts into laughter. Somewhat later a feeling of drowsiness may come on, but this is not constant;

[1] "A young man, a Mr. Davy . . . has made some discoveries of importance, and enthusiastically expects wonders will be performed by the use of certain gases, which inebriate in the most delightful manner, having the oblivious effects of Lethe, and at the same time giving the rapturous sensation of the Nectar of the Gods. Pleasure even to madness is the consequence of this draught." Maria Edgeworth, 1800.

the sensibility to pain is much less acute than normally, but no complete anæsthesia is produced by this mixture of gases; the sense of touch is comparatively little altered, and total unconsciousness never results. The pupil is generally slightly dilated, the face flushed, and the pulse somewhat accelerated.

When pure nitrous oxide is inhaled without the admixture of oxygen, the patient passes almost instantaneously through the symptoms already described, but then loses consciousness completely; the face is cyanotic, the respiration becomes stertorous and dyspnœic and ceases after a weak convulsion, while the heart continues to beat for some time afterwards. If the mask through which the patient has been inhaling the gas is removed when the cyanosis becomes marked, very complete anæsthesia lasts for thirty to sixty seconds, and the patient then recovers within a few minutes and suffers from no after-effects whatever. No prolonged anæsthesia can be produced, however, as the respiration becomes endangered if the mask be kept on longer than the beginning of the cyanotic stage.

Action.—Nitrous oxide supports combustion outside the body, for if a glowing splinter of wood be held in it, it bursts into flame exactly as if it were immersed in oxygen. In the tissues of the body, however, nitrous oxide behaves in the same way as any other indifferent gas, such as hydrogen or nitrogen; that is, the tissues exposed to it suffer from asphyxia owing to the oxygen of the air being excluded. Thus, plants do not grow in an atmosphere of nitrous oxide and seeds do not germinate. Animals die after inhaling nitrous oxide in almost the same time as after hydrogen or nitrogen, and at death the spectrum of the blood shows no oxyhæmoglobin to be present, the tissues having used up all the available oxygen. Nitrous oxide, therefore, does not support combustion in the animal body, the nitrogen is not split off from the oxygen at body temperature as it is when the oxide is exposed to high temperatures outside the body.

But nitrous oxide has a special effect on the central nervous system, although in the rest of the tissues it acts only by excluding the oxygen; it depresses the brain by virtue of its molecular form just as chloroform or ether does. This has been shown in a variety of ways; thus, if it were a perfectly indifferent body no more effect would be produced by it when mixed with one-fourth of its volume of oxygen than by air, which consists of 1 part of oxygen and 4 parts of an indifferent gas, nitrogen. But 80 per cent. nitrous oxide has definite effects on the behavior of animals, as has been mentioned, and even 73 per cent. produces some slowing of the respiration. The narcotic action was demonstrated very clearly by Paul Bert in a series of experiments on man and animals. He noted that only imperfect anæsthesia was produced by 80 per cent. nitrous oxide, while the pure gas produced asphyxia. The problem was to introduce as much gas into the blood as would pass in under pure nitrous oxide, and at the same time to supply sufficient oxygen to prevent asphyxia. The absorption of nitrous oxide depends upon its partial pressure in the lungs, as it is simply dissolved in the

blood without forming any real combination with it, and the quantity absorbed by the blood may be augmented by increasing the barometric pressure. Bert, therefore, administered a mixture of 80 parts nitrous oxide and 20 parts oxygen to animals in a glass case in which the pressure was raised one-fourth above the ordinary atmospheric pressure. The absorption of the nitrous oxide was the same as if the animal had breathed the pure gas at the ordinary air pressure, and at the same time as much oxygen was absorbed as in ordinary air. The result was a complete anæsthesia without asphyxia, which could be maintained for three days without injury to the animal (Martin). Kemp has shown that mixtures of oxygen and nitrous oxide can be inhaled for some time and produce anæsthesia, which passes off at once when nitrogen is substituted for nitrous oxide. He has further investigated the blood gases during nitrous oxide anæsthesia, and finds that the oxygen contained in the blood at the deepest stage of anæsthesia is quite sufficient to maintain life and consciousness were no nitrous oxide present. Again Goltstein found that frogs were narcotized in five and one-half minutes in an atmosphere of nitrous oxide, in one and one-quarter hours in hydrogen, and showed that the narcosis and death in mammals from nitrous oxide differed in several details from that under indifferent gases. There can, therefore, be no doubt that nitrous oxide has distinct effects on the central nervous system, although it is indifferent to the other tissues. The anæsthesia is due to a specific action on the nervous tissues although this may be reinforced by the asphyxia present. And Bert's and Martin's experiments would indicate that death occurs, not from the direct action of the nitrous oxide on the respiratory centre, but from the lack of oxygen, although the depression of the centre is undoubtedly a contributing factor.

The same question arises regarding the action on the nerve cells as has been met with in the members of the methane series, and here again the preliminary excitement may indicate not stimulation of the brain areas, but lessened activity of the functions of control and restraint.

The respiratory centre is depressed when the gas is inhaled in comparatively dilute form, for Zuntz and Goltstein found the breathing slower and deeper after 73 per cent. The respiration ceases somewhat earlier under nitrous oxide than under indifferent gases, which would indicate that the cessation of the breathing is due at any rate in part to the specific depressant action. In asphyxia from nitrous oxide there is less convulsive movement than under hydrogen, owing to the general depression of the nerve cells.

The circulation is little affected by the nitrous oxide directly, the rise in the blood-pressure and slowness of the pulse being due to the asphyxial condition of the blood; the pulse is not so slow as in ordinary asphyxia or in asphyxia from nitrogen or hydrogen, because the inhibitory centre is less capable of activity. The heart is not affected directly, but only by the lack of oxygen.

The blood dissolves more nitrous oxide than water, apparently

because it is taken up by the lipoids of the corpuscles in the same way as chloroform. Nicloux found about 40 mgs. in 100 c.c. blood at the beginning of anæsthesia, 50 mgs. in complete anæsthesia, and 60 mgs. when the respiration ceased.

Nitrous oxide is a gas at ordinary temperature and pressure, and is invariably administered by inhalation from a cylinder into which it has been forced under high pressure. The mask generally covers both nose and mouth, and the inhalation is carried on until distinct cyanosis appears, when the anæsthesia is sufficient to allow of short operations, such as those of dentistry. It is much the safest of the anæsthetics, for millions of persons have been subjected to its influence, and only a few cases of death are reported from its use, and several of these do not seem to have been due to the direct action of the gas. In experiments on animals Bock found that when oxygen was supplied to avoid asphyxia, a pressure of three atmospheres of nitrous oxide was the lowest fatal concentration; that is the fatal concentration is three times as great as that necessary for anæsthesia, a much greater difference between the efficient and the fatal dose than than holds for any other anæsthetic.

Ethyl chloride (see p. 228) has been introduced as a substitute for nitrous oxide, and has supplanted it to a certain extent, as it is more easily administered and the apparatus necessary is less cumbrous. On the other hand, nitrous oxide is responsible for much fewer accidents. Unfortunately, the anæsthesia cannot be kept up except for a very short time, which is quite insufficient to allow of ordinary operative procedures. A number of attempts have been made to prolong the anæsthesia, of which Bert's was much the most successful. The operator, patient and attendants were enclosed in an air-tight chamber, the air pressure was raised by means of force pumps, and Bert's mixture of oxygen and nitrous oxide was inhaled by the patient. A whole series of major operations were performed in this way, the anæsthesia being complete as long as was desired, and the patient recovering a few minutes after the mask was removed. But the method was expensive and the apparatus cumbrous, and Bert later proposed to induce anæsthesia by the pure gas and to maintain it by administering alternately pure nitrous oxide and nitrous oxide diluted with oxygen. A practical method of carrying out this form of anæsthesia has been devised by Hewitt, whose apparatus consists essentially of two reservoirs, the one containing oxygen, the other nitrous oxide, and of a mixing chamber with a stopcock by which the proportion of oxygen is regulated. The inhalation is commenced with pure nitrous oxide or with a mixture containing only 2 per cent. of oxygen. When anæsthesia is attained the percentage of oxygen is increased to 5–8 per cent. by turning the stopcock, and the symptoms determine the further changes, returning consciousness necessitating a diminution in the oxygen, stertor and cyanosis an increase. This form of anæsthesia is admirably adapted for minor operations and has been maintained in some cases for as long as an hour. The circulation and respiration are less seriously altered than by any

other method that induces general anæsthesia, and the return of consciousness is almost immediate. The great drawback to its use is the cumbrous apparatus required and the large amount of gas used, amounting to about 100 gallons for anæsthesia of half an hour. Complete muscular relaxation is seldom attained and this precludes its use in many operations, in which, however, it may be employed at first and then be replaced by chloroform or ether, whose preliminary disagreeable effects are thus avoided. In some operations 80 per cent. nitrous oxide has been used after partial anæsthesia had been attained by the hypodermic injection of morphine and hyoscine, and the results have been favorable. Klikowitsch proposed the use of 80 per cent. nitrous oxide, not for complete anæsthesia, but to relieve pain and spasm in cases of asthma, in labor and similar conditions. The patient could inhale it if necessary without the presence of a medical attendant, and it had the advantage over the other depressants that it need only be inhaled when an attack of pain was approaching and that it left no depression afterward. But 80 per cent. is apt to induce symptoms closely resembling those of alcoholic intoxication.

The high blood-pressure induced by nitrous oxide asphyxia is sometimes said to be dangerous in elderly persons from their liability to apoplexy, and of the few fatalities under the gas several would seem due rather to this than to the drug directly, but the danger is often overstated, and, in fact, it is a question whether the shock caused by the operation without gas would not be more dangerous than the effects of the gas itself. No such symptoms arise when the nitrous oxide is diluted with oxygen as in Hewitt's method.

Occasionally some glycosuria occurs after the inhalation, not owing to the gas itself, but to the accompanying asphyxia. It is merely temporary and has no practical importance.

The treatment of accidents in anæsthesia under nitrous oxide consists in artificial respiration alone.

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4. Soporifics.—Chloral Group.

Some twenty years after the introduction of the anæsthetics, a new interest was given to the methane series by the examination of chloral hydrate ($CCl_3CH(OH)_2$) by Liebreich. Henceforth the attention of investigators was diverted from the quest of anæsthetics to that of

hypnotics, with the result that a number of valuable drugs have been added to therapeutics. These soporifics, or narcotics, have the same general action as the anæsthetics, but are used only to produce the first effects of imperfect consciousness or sleep. The anæsthetics might be used for this purpose were it not for the comparatively short time during which their action persists. Narcotics are required to produce a slight but lasting effect, and for this purpose the gradual absorption from the bowel is better adapted than the rapid absorption and equally rapid elimination by the lungs. The narcotics are, therefore, less volatile than the anæsthetics, and ought to be soluble in water and not irritant in the stomach, so as to permit of rapid absorption. The most widely used members of this group are *chloral, paraldehyde, sulphonal* and *veronal,* but many others have received attention. They all resemble each other in their general soporific action, and that of chloral may be taken as typical of all; in their other characters some differences are presented and these will be taken up for each individual drug.

Symptoms.—Chloral in 15–30 gr. (1–2 G.) doses produces drowsiness and weariness, which soon pass into a condition resembling natural sleep very closely, from which the patient can be awakened by ordinary means, such as touching, loud sounds, or pain. The respiration and pulse are rather slower than in waking moments, but scarcely more so than in natural sleep, and the somewhat narrowed pupil and unaltered excitability of the reflexes are also common to both conditions. As a general rule, the sleep passes off in five to eight hours and leaves no unpleasant results, but sometimes headache, giddiness, and confusion are complained of. Occasionally no real sleep is produced by chloral, a condition exactly resembling alcoholic intoxication following its administration and continuing for some time.

When larger quantities (75 grs. or 3 G.) are taken, the sleep is much deeper, the patient cannot be aroused to complete consciousness, the reflexes are distinctly lessened and the sensation of pain is less acute, although no complete anæsthesia is present. The respirations are fewer and the pulse may be slow and somewhat weak. The sleep lasts very much longer (ten to fifteen hours), and nausea, vomiting, headache and confusion often remain after consciousness is regained. In still larger quantities chloral produces a condition resembling exactly the third stage of anæsthesia. The reflexes are entirely absent and no movement is elicited by painful operations, the muscles are completely relaxed, the respiration and pulse are both slow and weak, and eventually asphyxia occurs from paralysis of the respiratory centre. The heart continues to beat for a short time after the breathing ceases. The pupil is often contracted to pinhole size before death in fatal poisoning.

The first stage is the only one elicited in therapeutics. The use of chloral as an anæsthetic in man would be quite unjustifiable, because it is impossible to adjust the dose accurately enough to allow of complete anæsthesia without danger of respiratory failure.

Action.—The **Central Nervous System** is depressed and eventually completely paralyzed by chloral and its allies. Unlike the anæsthetics and alcohol, however, chloral rarely causes excitement, but this may be due to the facts that the surroundings of the patient are less likely to cause excitement and that the drug itself causes less local irritation. The results of psychological experiments on the effects of small doses of the narcotics seem to indicate that they all depress the sensory or receptive functions of the brain, while its motor activity is much reduced by chloral and sulphonal, but may appear to be actually increased by paraldehyde; this apparent stimulation is analogous to that under alcohol and may be explained by lessened control. The sleep induced by the dulling of the perceptions may be interrupted by more intense stimuli from without. In particular, acute pain may prevent sleep after chloral, which seems to have no specific effect on pain sensation such as is possessed by morphine. In larger quantities, however, even very great disturbance of the environment produces no interruption of the sleep, and the reflex response to irritation is very much lowered. The motor areas of the brain cortex are rendered less irritable by chloral, and eventually fail to react to the strongest electrical stimulation. The reflexes of the spinal cord are depressed and finally paralyzed before the failure of the respiration; this depressant action on the spinal reflexes is much more marked than that seen under morphine. The last part of the central nervous system to be attacked is the medulla oblongata, for although the respiration is somewhat slower and shallower after small quantities, it is scarcely more affected than in ordinary sleep, and Loewy found that both the excitability of the centre and the volume of the inspired air were very similar in the two conditions. As the dose is increased, however, the respiration becomes very slow and weak, and finally ceases from paralysis of the centre.

The heart is slower after chloral in moderate doses, but scarcely more so than in natural sleep. There is often some flushing of the face and head from some obscure central action, but the blood-pressure is little affected in the therapeutic use of the drug. In poisoning, the blood-pressure is reduced by weakness of the vasomotor centre and of the heart, the latter manifesting itself also in slowing of the pulse. This action on the circulation from poisonous doses is more evident under chloral than under the other hypnotics which do not contain chlorine. The same difference is met with in ether and chloroform, of which the latter affects the circulation more strongly. And the action on the heart in chloral poisoning resembles that of chloroform, the auricles being affected sooner than the ventricles and the strength of contraction falling more than the rate.

Locally, chloral has an irritant action when applied in concentrated solution and this leads occasionally to nausea and vomiting when it is prescribed with insufficient fluid. This irritant action induces redness and even vesication when chloral is applied to the skin; it is said to corrode when applied to unprotected surfaces, and certainly possesses disinfectant properties like chloroform. It is rapidly absorbed when

given by the mouth and is carried to the central nervous system where it is taken up by the cells until they contain more than the blood corpuscles or the cells of other organs, such as the liver. Liebreich introduced chloral as a hypnotic in the belief that it was decomposed in the blood and chloroform liberated, but this has been shown to be erroneous, no chloroform being found in the blood or expired air after chloral. Chloral has no action on muscle or nerve in the living animal, but when it is applied to the exposed nerve it first irritates and later paralyzes it, and injected directly into the artery of a muscle it causes immediate rigor. The temperature falls after the administration of chloral from the lessened muscular movement, and perhaps from the increased output of heat through the dilated skin vessels.

The effects of chloral on the tissue-change have been found to correspond to those of chloroform in character, but are very slight and seldom observed; fatty degeneration of various organs has been caused in animals by prolonged administration of large doses, and the usual changes in the urine have accompanied it. The muscular movement being reduced by the narcosis, less oxygen is absorbed and less carbonic acid is excreted by the lungs. Chloral was formerly supposed to lead to glycosuria, but this has been shown to be erroneous, the reducing substance in the urine being urochloralic acid, and not sugar.

Chloral is reduced in the tissues to trichlorethyl alcohol (CCl_3CH_2OH), which combines with glycuronic acid to form urochloralic acid, and is excreted in this form in the urine. Some escapes by the kidneys unchanged, however, and some is thrown into the stomach, and this may contribute to the nausea and discomfort felt after awaking in some cases.

The other hypnotics of this series, with the exception of chloralose, correspond exactly with chloral as far as their action on the central nervous system is concerned. The chief difference in their effects is seen in the circulation and metabolism, which are even less affected by those which do not possess substituted chlorine atoms.

Paraldehyde ($C_6H_{12}O_3$), a polymer of ethylaldehyde, resembles alcohol in its effects though it is a much more powerful narcotic and rarely induces any symptoms of excitement. It does not affect the heart directly even in large doses and has no such effects on the protein metabolism as have been observed under the prolonged administration of chloral; the pulse is slightly slower and the carbonic acid exhaled is less than normally, but these changes are due to the muscular movements being lessened, and are hardly greater in extent than occur in natural sleep. Very large quantities have been taken without fatal results, and in fact without any more serious consequences than prolonged unconsciousness. Paraldehyde, however, has a most unpleasant odor and a hot, burning taste, which renders its administration somewhat difficult. In addition it is excreted in part by the lungs, though mainly in the urine, and the odor remains in the breath for some time after the patient awakens.

Sulphonal ($(CH_3)_2C(SO_2C_2H_5)_2$) and its allies, **Trional** ($C_2H_5CH_3C(SO_2C_2H_5)_2$) and **Tetronal** ($(C_2H_5)_2C(SO_2C_2H_5)_2$), have no immediate action on the circulation even in large doses, though it is stated that

their prolonged use is deleterious to the heart, and they appear to be more uncertain in their narcotic action in cases of heart disease than in other conditions. They are practically tasteless powders, and are therefore easily taken, but their insolubility in water renders their absorption slow and uncertain, and sleep is therefore late in following their administration, while, on the other hand, depression, drowsiness and lack of energy are often complained of the day after. There is some evidence that they exercise a deleterious effect on the liver, for the relation of urea to the total nitrogen of the urine is changed and the metabolism of the purine bodies is also affected.

The use of the sulphonal group, especially when prolonged, has led in many cases to a series of symptoms, the most characteristic of which is the appearance in the urine of a reddish-brown pigment, hæmatoporphyrin, an iron-free product of the decomposition of hæmoglobin. This occurs most frequently in anæmic women, and is accompanied by constipation, pain in the stomach region and vomiting, weakness and ataxia, confusion and partial paralysis, and eventually by suppression of the urine or by collapse and death. These symptoms may appear several days after a single dose, sometimes after an interval of one or two weeks. The excretion of hæmatoporphyrin in the urine appears due to some obscure change in the liver; it occurs in traces in the rabbit's urine normally and in larger quantities after the animal has been treated with sulphonal (Neubauer). In other animals the prolonged administration of only a few doses. Very large doses are said to produce convulsive movements in animals, while ordinary ones cause sleep and subsequent drowsiness. Sulphonal is decomposed in the body and is excreted largely as ethylsulphonic acid in the urine, in which traces of the unchanged substance have also been found. The decomposition is a slow process, however, for Kast found sulphonal in the blood many hours after its administration. The ethylsulphonic acid seems to have no action whatever in itself, so that the narcosis is due to the unchanged molecule of sulphonal.

Veronal, diethylbarbituric acid ($(C_2H_5)_2C(CONH)_2CO$), and its sodium salt, *medinal* ($NaC_8H_{11}O_3N_2$), seem to be devoid of action except on the central nervous system, and thus approach the ideal more closely than any of the others. In ordinary doses (5–10 grs.) they induce natural sleep without subsequent depression, and larger quantities deepen and lengthen the unconsciousness without other organs than the central nervous system being involved, though the patient may complain of lethargy and drowsiness subsequently. Fatal poisoning has occurred from very large quantities (*e. g.*, 150 grs.), the sleep passing into coma, ending in respiratory failure. From 50–90 per cent. has been recovered unchanged from the urine, the rest apparently undergoing oxidation in the tissues. They act as hypnotics in smaller quantities than any of the others of this series. In some animals veronal causes increased reflexes and even general convulsions, but this effect has not been seen in man.

Two recent hypnotics nearly related to Veronal are **Luminal** or phenyl-

ethyl barbiturate and **Dial** or diallyl barbiturate, of which the second is preferable; it is the most powerful hypnotic of all the group, the dose in man being 0.1–0.3 G.

Butylchloral, or **Crotonchloral** ($C_3H_4Cl_3CH(OH)_2$), was said by Liebreich to possess a specific analgesic action on the nerves of the face and head, but this has been shown to be incorrect, and, as its effects are identical with those of chloral in almost all respects, crotonchloral seems entirely superfluous.

Chloralamide, or chloralformamide ($CCl_3CHOH–NHCHO$), was introduced as tending to depress the heart less than chloral, but this has not been demonstrated. It is said to be less irritant than chloral in the stomach, but to be somewhat slower and less certain in its effects. Chloral is formed by its decomposition in the body, and is excreted as urochloralic acid.

Chloralose ($C_8H_{11}Cl_3O_6$), a sugar compound of chloral, acts much more like morphine than like chloral, depressing the psychical functions, while increasing the reflexes until convulsions resembling those of strychnine may be produced. The heart is comparatively little affected, and the respiration remains strong unless very large doses are given. In man it induces sleep, which is sometimes attended by distinctly exaggerated reflexes, however, especially when large doses are given.

Amylene Hydrate, or dimethylethylcarbinol ($(CH_3)_2COHCH_2CH_3$), is closely allied to paraldehyde in its effects but is twice or thrice as powerful, while it is only one-half as strong as chloral. It is said to depress the heart more than paraldehyde, but less than chloral, and to produce excitement and convulsions in the carnivora, but not in the herbivora. Even in man, it causes excitement more frequently than most other soporifics, and Harnack and Meyer state that it first stimulates and then depresses the respiratory centre as well as other parts of the central nervous system, and that it induces a very marked fall in the temperature. It has little or no effect on the general metabolism, and is excreted in the urine in combination with glycuronic acid in the rabbit, but is exhaled by the lungs for the most part by the dog and possibly by man. It is less certain in its action than chloral but has not received so wide a trial as it would seem to merit. A combination of chloral and amylene hydrate has been introduced under the name of **Dormiol,** but offers no advantages over chloral.

Urethane, or ethyl carbamic ester ($CONH_2OC_2H_5$), is too weak and inconstant in its action in man to be satisfactory. In many cases it is an almost perfect hypnotic, especially in children, producing light sleep with no after-effects, but in others it seems to have little or no hypnotic effect. It is oxidized in the body to urea. **Hedonal,** the amyl carbamic ester ($CONH_2OC_5H_{11}$), appears to have a greater hypnotic effect than urethane, but also fails to induce sleep in a considerable proportion of cases. It is followed by no after-effects and is oxidized in the body in the same way as urethane. Other carbamic esters suggested are **Aponal,** another amyl carbamate, isomeric with hedonal, and **Aleudrin,** dichlorisopropyl carbamate.

Bromoform, ($CHBr_3$) has anæsthetic properties like chloroform, but is not volatile enough for inhalation. Of late years it has been used internally in whooping-cough, and in this relation it is important to remember that it gives rise to fatty degeneration when taken continuously. A number of cases of alarming poisoning in children have been recorded from its use. It has also been used occasionally in insomnia.

Bromal (CBr_3COH) differs in several respects from chloral in its action. In animals its injection is followed by restlessness and excitement, and then by stupor, which is often accompanied by dyspnœa, and ends in failure of the respiration, or in convulsions. The pupil is much contracted, and profuse salivation is observed. It acts on the heart like chloral but is much more poisonous, and is scarcely used in therapeutics.

Chloretone, trichlorpseudobutylalcohol ($CCl_3C(CH_3)_2OH$), resembles chloral in most respects, but is less liable to irritate the stomach. Very large doses have been swallowed without producing any untoward symptoms, but the hypnotic effect is obtained by the use of smaller doses than are necessary in the case of chloral. Like chloral, chloretone has some virtues as an antiseptic, and in addition it paralyzes the terminations of the sensory nerves when it is applied locally and has proved of value as a local anæsthetic.

Isopral, trichlorisopropylalcohol (CCl_3CHCH_2OH), resembles chloretone closely.

Many other similar bodies have been introduced as hypnotics, but have not proved to possess any advantages over those already enumerated. Among these are hypnone ($C_6H_5COCH_3$), neuronal ($(C_2H_5)_2BrCCONH_2$), bromural, brometone, nirvanol and adalin.

Tolerance is soon acquired for each of these drugs, and when it is developed for one, large doses of any of the others are required in order to produce sleep. Tolerance for alcohol also involves the use of larger quantities of the hypnotics, and in fact often leads to the complete failure of any except the most powerful.

Not infrequently the hypnotics lead to skin eruptions, especially when used for some time. These assume various forms, the most common being of the erythema order, but among others urticaria, purpura, papular eruptions and blisters occur.

Habit.—Prolonged abuse of chloral leads to a condition somewhat resembling that seen in chronic alcoholism or morphinism, and marked by general depression and cachexia, with impairment of the mental powers, digestive disturbance and exanthemata. The sudden withdrawal of the drug in these cases has sometimes led to symptoms resembling those of delirium tremens. Cases of sulphonal and veronal habit have also been reported with symptoms resembling those of the chloral habit.

Preparations.

Chloralum Hydratum (U. S. P.), Chloral Hydras (B. P.) ($CCl_3CH(OH)$ or (CCl_3COH+H_2O)), a crystalline solid, of a characteristic pungent odor, and hot, acrid taste, readily soluble in water, alcohol, ether and oils, is almost invariably prescribed in dilute solution in syrup. Its deliquescent properties preclude its use in most of the solid preparations, and its irritant effects contraindicate hypodermic injection. Dose, 0.5 G. (8 grs.); B. P., 5–20 grs., which may be repeated if necessary, in one or two hours.

Syrupus Chloral (B. P.) (20 per cent.), ½–2 fl. drs.

Paraldehydum (U. S. P., B. P.) ($C_6H_{12}O_3$) a colorless fluid of strong, characteristic odor and burning taste. It may be prescribed in brandy and water, or in water up to 10 per cent., or in capsules. 2 mils (30 mins.); B. P., ½–2 fl. drs.

Barbitonum (B. P.), Veronal ($(C_2H_5)_2C(CONH)_2CO$, colorless crystals with a faint bitter taste, soluble in 145 parts of water; prescribed in powders or tablets, to be dissolved in warm water or milk. Dose, 0.3–0.5 G. (5–8 grs.).

Sulphonal (B. P.), Sulphonmethanum (U. S. P.) ($((CH_3)_2C(SO_2C_2H_5)_2)$), a crystalline powder, without taste or odor. It may be prescribed in powder form to be taken one to two hours before retiring, but is soluble in hot water or milk, and when given in solution acts more rapidly and leaves less confusion afterward. It is prescribed in doses of 0.75 G. (12 grs.); B. P. 10–30 grs.

Sulphonethylmethanum (U. S. P.), *Methylsulphonal* (B. P.), *Trional* ($(CH_3)(C_2H_5)C(SO_2C_2H_5)_2$) resembles sulphonal, but is more soluble and has a bitter taste. 0.75 G. (12 grs.); B. P., 10–20 grs.

Æthylis Carbamas (U. S. P.), urethane ($CO{\cdot}OC_2H_5{\cdot}NH_2$), colorless crystals, odorless, with a cool, saline taste, very soluble in water, alcohol, and ether. Dose, 1–5 G. (15–75 grs.). U. S. P., 1 G. (15 grs.).

Bromoformum (U. S. P.) ($CHBr_3$), a heavy, transparent, colorless liquid with an ethereal odor and a taste like that of chloroform, very little soluble in water, but readily soluble in alcohol. Dose, 0.2 mil (3 mins.).

Chloral Formamidum (B. P.), or chloralamide ($CCl_3CHOHNH{\cdot}COH$), a white crystalline powder with a faintly bitter taste; prescribed in powder or in solution in water or spirit. Dose, 15–45 grs.

Unofficial.

Tetronal resembles sulphonal closely, and may be prescribed in the same dose and form.

Medinal or sodium veronal, a white crystalline powder soluble in 5 parts of water with a bitter alkaline taste. Dose 0.3–0.6 G. (5–10 grs.) in water.

Amyleni Hydras ($(CH_3)_2COHCH_2CH_3$), a colorless liquid of pungent taste, and of an odor somewhat resembling camphor. It may be prescribed in capsules, or up to 10 per cent. in water. Dose, 3–5 c.c. (40–80 mins.).

Hedonal, a crystalline powder with a taste resembling that of menthol, very slightly soluble in water. Dose, 2 G. (30 grs.) in powder or tablets.

Chloretone ($CCl_3C(CH_3)_2OH$), colorless crystals with a strong camphoraceous odor, slightly soluble in water, very soluble in alcohol; it may be prescribed in tablets. Dose, 0.3–1 G. (5–15 grs.).

Proponal differs from veronal only in having propyl substituted for ethyl, and is used in the same dose.

Isopral ($C_2H_3Cl_3CHOH$), white crystals with a camphoraceous odor and aromatic biting taste, soluble in 30 parts of water; prescribed in doses of 0.5–0.75 G. (5–8 grs.).

Therapeutic Uses.—In ordinary practice chloral and veronal are the best of the group. Sulphonal and its allies should be avoided on account of their capricious poisonous action. Paraldehyde is disagreeable, but has been advised as a substitute for chloral in cases where there is a tendency to form the habit, as here its disagreeable properties are of advantage. Other drugs which are used to cause sleep are opium and morphine, cannabis indica, alcohol, bromides, and hyoscine.

The hypnotics are chiefly used to produce rest and sleep in cases of insomnia, and in almost every form of nervous excitement. Until the discovery of the therapeutic value of chloral, opium was used in most of these cases, and when sleeplessness is due to pain it is still preferable to the more modern remedies, which have comparatively slight influence on acute pain, except in very large doses. But in delirium, mania and convulsions of various kinds, their action on the nerve centres is preferable to that of opium, especially where these convulsions are of spinal origin or of a reflex nature; thus, in strychnine poisoning and in tetanus, chloral is of great value, although in the former it may have to be reinforced by chloroform during the convulsions. In delirium from fever or from uræmic intoxication and similar causes, comparatively small doses often produce most satisfactory results, and in various spasmodic affections, such as cough, asthma and choreic movements, it is exceedingly useful. Chloral has also been advised to lessen the pains of labor.

Most of the soporifics have been used more or less extensively as hypnotics in simple insomnia and in insanity, but when the disturb-

ance assumes a more violent character there is a disposition to return to the use of chloral, as at once the speediest and surest remedy of the whole group. When there is any reason to suspect fatty degeneration of the heart, however, some hypnotic which does not contain chlorine ought to be substituted for it, and paraldehyde, hedonal and veronal have been introduced in succession to supply the need. In other forms of heart disease, chloral may be used without danger and is often of great value as a hypnotic; the dread of its affecting the heart deleteriously in ordinary doses is quite unfounded. Chloral is often prescribed along with opium, and, when thus combined, smaller quantities of each drug are required than would be necessary if either were prescribed alone, and the sleep following is very deep and restful. It is also used to reinforce the action of the bromides.

Chloral has been used externally as a counter-irritant and antiseptic, but is more expensive than many other equally efficacious remedies. Chloretone solution is an efficient local anæsthetic on wounded surfaces, and has been recommended in cases of gastric irritation and vomiting, which it relieves by paralyzing the terminations of the sensory nerves in the mucous membrane of the stomach.

In cases of acute **Poisoning** with chloral, the treatment consists in the immediate evacuation of the stomach by the stomach tube. Emetics are of less value owing to the depression of the medullary centres. The patient ought to be kept warm, and caffeine or strychnine may be given as a respiratory stimulant, while the complete failure of the breathing has to be met by artificial respiration. In acute poisoning with the other members of the series the same general treatment is to be applied. When a patient has formed the habit of taking one of these drugs, it is generally necessary to send him to a retreat. It seems advisable to withdraw the drug gradually.

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II. OPIUM SERIES.

Opium has been used in medicine since a very remote period, and although many substitutes have been proposed for it of late years, it still occupies a position of its own in therapeutics. It is the dried juice of the Papaver somniferum, a poppy which is grown chiefly in India, China, Egypt, Persia and Asia Minor, but has been cultivated in colder climates and is said to produce a more powerful opium there. Opium owes its activity to a large number of alkaloids, of which *Morphine, Codeine, Papaverine, Narcotine,* and *Thebaine* are the most important.[1] The total alkaloids in opium vary from about 5–25 per cent., and different specimens may contain very different quantities of each alkaloid; for instance, morphine may vary from 2.7–22.8 per cent. The average percentage of morphine is 10, of narcotine 6, papaverine 1, codeine 0.5, thebaine 0.3 and narceine 0.2; the others occur in too small quantity to have any influence on the action of the crude drug. The alkaloids are found in opium in combination with meconic, lactic, and sulphuric acids. The empirical formulæ of most of the alkaloids have been determined, those of the most important being morphine ($C_{17}H_{19}NO_3$), codeine ($C_{18}H_{21}NO_3$), narcotine ($C_{22}H_{23}NO_7$), papaverine ($C_{20}H_{21}NO_4$), thebaine ($C_{19}H_{21}NO_3$). Morphine, codeine and thebaine are derivatives of pyridine and phenanthrene ($C_{14}H_{10}$); the morphine molecule contains two hydroxyls, one of which is substituted by methoxyl in codeine, and in thebaine both are thus substituted and some other changes occur in the constitution. Narcotine, papaverine and most of the other alkaloids are derivatives of benzene and isoquinoline. The pyridine-phenanthrene group of alkaloids differs considerably in action from the benzyl-isoquinoline derivatives and is diametrically opposed to them in some respects.

The action of opium is mainly due to the large amount of morphine contained in it, though the other alkaloids may modify its effects. Morphine acts chiefly on the central nervous system, but it also affects some peripheral organs, such as the intestine; its action varies considerably in different animals.

Symptoms.—In **Man** small quantities of morphine ($\frac{1}{8}$ gr., 8 mgs.) lessen the voluntary movements and produce a drowsiness which soon passes

[1] Others are Pseudomorphine, Codamine, Laudanine, Laudanosine, Meconidine, Lanthopine, Cryptopine, Protopine, Papaveramine, Rhœadine, Oxynarcotine, Narceine, Hydrocotarnine, Gnoscopine (or racemic Narcotine), and Tritopine; many of these occur only in traces.

into sleep, unless the patient is continually aroused by his surroundings. As long as he is kept awake, his actions and movements show nothing abnormal, but it is impossible to keep his attention directed to any object for long, and as soon as he is left to himself for a few moments he sinks into sleep. After small quantities there is no difficulty in arousing him; in fact, the sleep seems lighter than usual and may resemble rather a state of abstraction or "brown study." In this condition (euphoria) the imagination is not depressed to the same extent as the reason; the self-control and judgment are lessened, and although the stream of thought may seem more rapid and the images more vivid than usual, the logical sequence and the ideas of time and space are lost, and the condition may rather be compared to dreaming than to a real increase of the intellectual powers. This stage of abstraction is not by any means generally observed and soon passes into sleep, but the unchecked imagination may still persist in the form of dreams. Even in this early stage pain is felt less acutely, the respiration is slow, and the pupil contracted.

In larger quantities ($\frac{1}{4}$–$\frac{1}{2}$ gr., 15–30 mgs.), morphine produces deep, dreamless sleep, from which the patient is still easily aroused, but which returns at once when he is left undisturbed. When once aroused, he can be kept awake or can be aroused again after a short interval much more easily, some time elapsing apparently before the same degree of depression is reached again. As the dose is increased, the sleep deepens into torpor, from which he can be awakened only with difficulty, and eventually all efforts to arouse his attention are fruitless and he sinks into coma, which may be reached very soon after a large dose. During this deeper sleep and coma the respiration is very slow, the pulse is regular, full, and of moderate speed. The pupils are contracted to a small point and the mouth and throat are dry. The face is purple and congested, and the skin feels warm, although the temperature may be low. The breathing generally becomes slower and weaker, and occasionally periodic (Cheyne-Stokes). The cyanosis increases, the pulse becomes smaller and often quicker, the pupils remain contracted, but dilate widely just before the final arrest of the respiration. The heart continues to beat feebly for a short time afterwards.

After small doses of morphine the patient generally awakes refreshed, and, save for occasional dryness of the throat and slight nausea, apparently quite normal. Not infrequently, however, headache is complained of, and sometimes nausea and vomiting, accompanied by marked depression. In rare cases delirium, and even convulsions, have been observed soon after its injection, but these symptoms of excitement are so rare in the human subject as to be classed as idiosyncrasies. Some skin affections, such as itching, and redness, are occasionally seen while the action is passing off.

The lower **Mammals** are much less susceptible to morphine than man, and the action differs in the different species and, to a less extent, among the individuals of the same species. While in man depression of the central nervous system is the dominating feature, the lower animals often exhibit symptoms of excitation of some nervous

areas. In the dog, the first symptom is not infrequently vomiting and defecation, and then the animal passes into a light sleep, from which he can be easily aroused by touching or by noise, but which rapidly becomes deeper, so that greater force has to be used to waken him. When once awakened, he seems to sleep less heavily for a short time, and a much slighter stimulus is enough to arouse him if it is applied soon afterwards. When awakened he may perform apparently voluntary movements for a short time, although more clumsily than in his normal state, but no complete consciousness is present, the animal is stupid and drowsy and soon sinks back into deep slumber again. The sensation of pain seems to be much lessened but not entirely abolished, and reflex movements are difficult to elicit. After larger quantities an exaggerated sensibility to external stimulation seems present, for the animal starts convulsively at loud sounds and on pinching, but when left undisturbed lies in profound sleep. The respiration is at first quick and dyspnœic, the dog panting as if after a long run, but later it becomes slow and labored; the pupil is narrowed; the circulation seems less affected, although congestion of the skin and mouth is often observed. The reflex irritability may be distinctly increased by large quantities, and before the respiration finally ceases, convulsions generally occur, but these are asphyxial in origin and are not due to the direct action of the alkaloid.

In the rabbit and other rodents the symptoms are similar to those seen in the dog, but the depression is even more marked. An increase in the reflex irritability to external stimulation is also evident here, while the respiration is slowed from the beginning. In the cat and the other felidæ, morphine induces wild excitement which may last for several hours, the animal rushing round its cage and appearing unable to rest for a moment. This excitation is accompanied by a certain degree of depression of the intelligence, however, for no attempt to escape is made and obstacles are not avoided so carefully as by the normal animal. After large doses violent clonic and tonic convulsions may arise and prove fatal from exhaustion. Small quantities of morphine produce drowsiness in the horse, ass or goat, larger quantities restlessness and excitement which may pass into convulsions and death. In birds the action resembles that in the dog and rabbit.

The **Frog** is remarkably tolerant of morphine, no change whatsoever following the injection of quantities which would cause distinct symptoms in man. The first effects elicited are a diminution of the spontaneous movements, which become clumsy and ill-coördinated, and finally cease. This condition may last for several hours, when a series of symptoms of an entirely different nature appear. The reflex response to irritation is distinctly depressed during the first stage, but in this second phase it begins to return, and eventually a condition of exaggerated reflex irritability and spasms sets in resembling that seen in strychnine poisoning, except that the frog seems more easily exhausted. The animal often dies in this phase but it may survive to pass again through a stage of depression before regaining its normal condition. In fish morphine causes no depression, but is purely excitant, like strychnine.

Action.—The action of morphine on the **Central Nervous System** in man is mainly depressant, but it differs from the alcohol-chloroform group in its selective action on the respiration and on pain sensation, which are both much reduced by doses which have little effect on the general consciousness. The **Pain** of disease is deadened or even entirely removed, while the intelligence is almost as acute as usual, and the patient is able to answer questions and converse freely, and may seem unusually sensitive to impressions caused by loud noises or sudden flashes of light. But while a constant pain is alleviated, a sudden shock causes almost as much pain as without morphine, and when the patient is once aroused, the sensitiveness to pain apparently persists for some time. Morphine thus seems to lessen the power of attention, and under it the individual remains almost unconscious of any constant stimulus, but he can be aroused by a sudden intense stimulus and only relapses to his former lethargy after some time. This specific action on pain indicates that morphine depresses with special power the paths by which pain stimuli reach the consciousness; it has been suggested that it may interrupt these paths at their synapses in the region of the basal cerebral ganglia (Head).

There is accumulating evidence that small doses of morphine facilitate certain mental processes, while retarding others; this is accompanied by a feeling of freedom from the restraining conditions which previously limited activity; the imagination is untrammelled by its usual controls, and this may lead to unusual brilliancy of thought and expression. In psychological experiments, it is found that the simpler responses are facilitated; for example, the reaction time to flashes of light or to sounds is shortened, fewer errors are made in the association of words or in simple arithmetical computations. This condition is the attraction which proves so fatal to the devotees of the drug, and as the results of the habit are developed, this primary stage of its action is sought as a relief from them. How far this euphoria is a true increase in the mental capacity and how far it arises from the lessened appreciation of the distresses and distractions of life is not yet clear. It is present only after small doses, and soon gives way to lessened mental activity.

The motor areas of the cerebral cortex are not affected by small doses of morphine, but larger quantities lower and eventually abolish the excitability by electric shocks. The acuteness of sensation, as indicated by the smallest distance between two points on the skin which the patient can recognize as distinct, is reduced by morphine owing to the central depression; it has hardly any significant action on the sensory organs in the periphery.

While the effects of morphine on the central nervous system in man are chiefly depressant, and this is especially marked in pain sensation and respiration, some other areas seem to be exceptionally resistant to its action. Thus the circulatory centres in the medulla are little affected directly by quantities which depress the respiration to a dangerous extent. And there is, according to one view, an actual stimulation of the nerve centre which causes contraction of the pupil.

In animals, the central nervous symptoms of morphine poisoning present an extraordinary mixture of stimulation and depression and the relative prominence of these varies widely in different species. The stimulation of the brain is best manifested in the wild excitement of the cat and its allies under morphine, while the narcotic action predominates in the rabbit and to a less extent in the dog; even in the cat some depression of the intelligence is to be made out. In the cat and rabbit the respiration is depressed as in man, but in the dog there is a stage of marked acceleration present at first. In the dog the vomiting centre is excited and the cardiac inhibitory centre of the medulla is also stimulated. It is impossible at present to suggest any general theory of the action of morphine on the nerve cells which covers these differences in the behavior of different animals and also in the reaction of different nerve centres in the same animal.

The effect of morphine on the **Spinal Cord** has been studied almost exclusively in the frog. The reflex irritability in these animals is first diminished to a slight extent, and then increased to the same degree as by strychnine. In all animals the cord is less depressed than in the corresponding stage of chloral poisoning, for if two animals are poisoned, the one with morphine, the other with chloral, until no voluntary movements occur, the reflexes of the one poisoned with morphine are always found more active than those of the other.

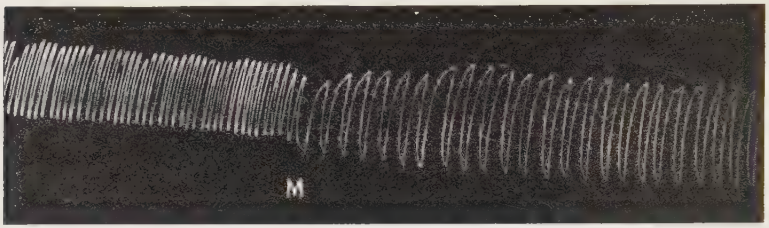
To sum up the action of morphine on the central nervous system, it produces great depression which is especially marked in the sensation of pain and in the respiration; the imagination and the cerebral motor functions are less affected than the power of perception, the will, and the attention. In man the failure of the respiration closes the course of the intoxication, but in the cold-blooded animals a further development of excessive reflex irritability follows which may pass into tonic convulsions. Even in the higher animals and man some indication of this action on the cord may occur, and in the feline group this stimulation involves not only the cord, but also the motor areas of the brain. It has been suggested that while morphine itself is depressant, a product formed by its oxidation in the body is stimulant, and differences in the rate of oxidation in different animals determine whether the primary or secondary effect predominates (McGuigan and Ross).

Respiration.—In man and in most other animals the respiration is slowed by morphine from the beginning[1] (Fig. 13), and as the dose is increased, the slowing becomes progressively greater. After small quantities the breathing may be rather shallower, especially if sleep follows; but as the rate slows the depth increases, though not sufficiently to compensate for the slowing, and the total air breathed may fall to one-half the normal or less. The characteristic effect of morphine is thus a diminution in the rhythm of the centre, which remains susceptible to reflex stimulation, but is unable to accelerate the discharge of impulses to the same extent as normally. The inhalation of carbon

[1] In the dog there is often a preliminary stage of rapid, panting respiration, which may be secondary to the emetic action in this animal.

dioxide in unpoisoned animals quickens and deepens the respiration, but under morphine, while it deepens it as much as before, it is unable to quicken it in the same measure. If morphine causes rest and sleep, less carbon dioxide is formed in the tissues and though less is excreted owing

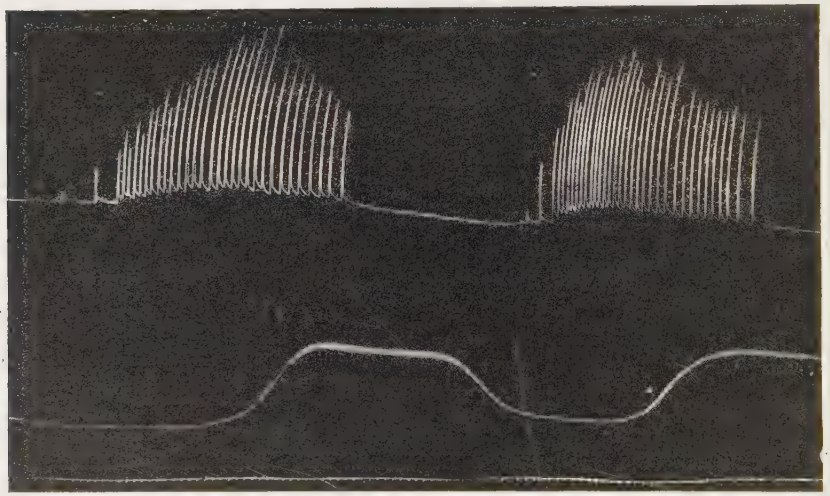
FIG. 13



Respiration of the cat. At *M*, injection of morphine intravenously. The respiration is immediately slowed and the movement is increased in depth.

to the slowness of the breathing, there may be no accumulation in the blood and the depth of the respiration remains unchanged or may be shallower. But if the slowing is more marked, the gas accumulates in the blood and acting on the respiratory centre deepens the breathing, as it cannot accelerate it except to a limited extent.

FIG. 14



Tracings of the respiration (upper) and blood-pressure (lower) during Cheyne-Stokes respiration in a cat under a large dose of morphine. (Barbour.)

In the later stages of morphine poisoning, the breathing often becomes irregular, and this irregularity may have a periodic character, a series of deep respirations being followed by several progressively weaker ones and then by complete inactivity for several seconds. The breathing

then recommences with a very slight movement, followed by a series increasing regularly in strength and then again decreasing (Fig. 14). This form of respiration (Cheyne-Stokes) appears to arise in part from the depression of the respiratory centre, in part from the asphyxia of the heart, which results from the inefficient respiration and which leads to periodic variations in the blood-pressure and in the blood-supply to the brain (Barbour). When the respiratory centre is once aroused by the accumulation of carbon dioxide and by the anæmia, it remains less narcotized for some time and thus a series of respirations follow which reduce the carbon dioxide of the blood and also relieve the asphyxia of the heart. The blood-supply to the brain increases, and thus the stimuli to the respiratory centre furnished by the carbon dioxide and the anæmia are both removed and the centre again becomes dormant (Fig. 14) until asphyxia of the heart and the carbon dioxide again arouse it to a new phase of activity.

Towards the end the respiration becomes gradually slower and weaker, and often loses its periodic character. Even after consciousness fails to be aroused by the most powerful shocks, some influence may be exerted on the respiratory centre. Thus the sudden application of cold water may cause several deep respirations, although it fails to dispel the stupor, but the respiration finally fails to react to these applications and soon afterwards ceases.

Jackson has recently noticed that morphine and many of the other alkaloids of opium constrict the bronchi in animals; this appears to arise from a direct action on the bronchial muscle. It is not known that any such effect occurs in man in morphine poisoning.

Morphine has little direct action on the **Circulation** in man; the heart is often slightly accelerated at first, perhaps from the slight nausea. In the dog the heart is slow and irregular from powerful stimulation of the vagus centre.

The blood-pressure remains high and the peripheral arteries in general show no change of calibre, with the exception of those of the skin, especially of the head and neck, which are dilated, rendering the face flushed and hot; as asphyxia comes on the flush becomes more dusky and cyanotic, but the vessels remain dilated, so that the face is of a bloated, purple color. The dilatation of these vessels, which is due to some obscure central action, has little influence on the general pressure, but causes a sense of warmth in the skin, which is occasionally followed by itching and discomfort. It may account in part for the increased perspiration often observed, although this is doubtless contributed to by other factors. As asphyxia advances, the pulse may become slow, while the blood-pressure varies, either rising from the asphyxial activity of the vasomotor centre or falling from the slowness of the heart. These effects are entirely absent if the blood is sufficiently aërated by artificial respiration, and are, therefore, to be regarded as indirect results of the action on the respiratory centre.

The selective action of morphine is thus well illustrated in its effects on the medulla oblongata in man, for the respiratory centre is par-

alyzed before the centres for cardiac inhibition and vaso-constriction are affected to any marked extent.

The peripheral **Muscles** and **Nerves** are also unaffected by morphine in any except overwhelming doses. Even when directly applied to the nerve it has but little effect on the irritability (Waller). It is often stated that the sensory terminations are paralyzed by morphine, and solutions are therefore injected into the seat of pain, or liniments are rubbed into the skin over it, but as a matter of fact, morphine seems to possess only an insignificant local action. The sensibility of the skin is lowered by an injection, it is true, but this is due to the central action almost entirely.

In morphine poisoning in man, the **Pupil** is contracted to pin-hole dimensions until just before the final asphyxia, when it dilates widely. In some animals, such as the dog and rabbit, the same effects are seen, while in birds the pupil remains unaffected, and in animals in which morphine causes movement and excitement, it is dilated widely. The contraction arises from direct or indirect stimulation of the oculomotor centre,[1] and not from any local changes in the eye, for when applied directly to the conjunctiva morphine has no effect; atropine applied to the conjunctiva at once removes the myosis produced by morphine. The terminal dilatation seen in man is not due to any direct action of the poison, but is a result of the general asphyxia.

As a general rule the **Secretory Glands** seem to be rendered less active than usual by morphine. When it produces nausea it may increase the saliva and the mucus, but these are the usual accompaniments of this condition and cannot be considered due to any special action. The sweat glands are exceptions to the general rule, however, for slight perspiration is generally observed from the therapeutic action, and profuse perspiration is seen before death in some cases in man from the effects of the asphyxia. The urine does not generally show any distinct alteration after morphine in man, but there is not infrequently retention in the bladder because the sphincter is powerfully contracted.[2]

The **Alimentary Canal** manifests some distinct changes under morphine, which have not yet been completely explained. In the human subject its injection is occasionally followed by some nausea, which is much more frequently present, however, during recovery from the drug. In the dog nausea and vomiting are almost invariable sequelæ of its application in any form, and seem to be due to its acting on the medullary centre. Small quantities of opium or morphine lessen the sensation of hunger in the human subject, but this is probably to be attributed to central action rather than to any effects on the stomach. Riegel states that in man and the dog the gastric secretion is generally retarded at first but is subsequently increased

[1] It is often stated that this contraction arises from depression of a centre which normally inhibits the activity of the oculomotor centre, but this is not founded on reliable experiments.

[2] The anal sphincter is similarly contracted in some animals, and in the mouse this leads to a curious stiffening of the tail, which was at one time considered a specific test for morphine, but has been shown to be induced by many other poisons.

to a considerable extent. This occurs whether the drug be administered by the mouth or hypodermically and is therefore due to some change induced by it after absorption. The pancreatic secretion is lessened by morphine from direct action on the gland. The rate of absorption in the stomach and bowel appears to be unchanged by morphine.

The effects on the intestine vary with the species of animal. In man morphine slows the peristalsis and induces constipation, and in most animals small quantities have this effect; opium and morphine are very extensively used in therapeutics to quiet the movements of the bowel. Magnus found that the constipating action could be elicited after all the nerves to the stomach and bowel were divided, so that it is quite independent of the action on the central nervous system. He states that the passage of food through the stomach is much delayed in the cat through a persistent contraction of the sphincter antri pylorici which keeps the contents in the cardiac end, and later of the pyloric sphincter which delays their passage into the duodenum. Their passage through the bowel is also slower than usual, and this retardation of the intestinal peristalsis is especially marked when it has been previously accelerated by irritant purgatives such as colocynth. This slow passage of the contents along the canal permits of more complete absorption of the fluids and thus leads to the stools being fewer and of firmer consistence. In addition there is less secretion from the intestinal mucous membrane under morphine. In man, the effects of morphine on the movements of the alimentary canal resemble those in animals in general characters. But the delay in the stomach is less marked, while that in the intestine is greater. The contents pass through the small gut more slowly than normally and make a prolonged stay in the cæcum and lower part of the ascending colon, and this delay in the large bowel is the chief factor in the constipation. The action in slowing the gastric movements is most marked in the young and may be almost unnoticeable in adults (Zehbe). Larger quantities are required to act on the stomach than on the bowel in diarrhœa (Takahashi). In both cases the action is a peripheral one in the wall of the stomach and bowel. Very large doses cause violent peristalsis and repeated evacuation of the bowel in the dog and cat, but this effect does not occur in man even in morphine poisoning.

In animals many forms of **Unstriated Muscle**, such as intestine, ureter, uterus, bronchial muscle and bladder, have been shown to be aroused to increased contraction and tone under the influence of morphine and the other phenanthrene alkaloids, while the isoquinoline derivatives depress their activity; after repeated injections the contractions from the phenanthrene group fail to occur, while the organ continues to respond to various other poisons. It is unknown whether the action is exerted on the muscle directly or on the peripheral nervous structure. There is no reason to suppose that this effect occurs in man, even in poisonous doses.

Morphine frequently causes a fall in the **Temperature**, partly from the

diminished movement by which less heat is formed, but mainly by the great loss of heat from the dilation of the skin vessels; sometimes a slight preliminary rise in the temperature has been seen in man. It is found that animals under morphine react less to an increase in the surrounding temperature than unpoisoned ones; *i. e.*, a normal animal exposed to a high temperature takes measures to prevent its internal temperature from rising above the normal, while, under morphine, these measures are less effective, and the temperature rises more rapidly and to a greater height; this indicates that the temperature centre in the brain is rendered less sensitive and that it is therefore important to avoid exposure to cold in cases of opium poisoning.

Metabolism.—The excretion of carbonic acid is lessened during the depression stage, while in those animals in which excitement is produced, it may be considerably augmented from the increased muscular movement. The imperfect respiration leads to an increase in the lactic acid of the blood and urine and to the disappearance of glycogen from the liver. Sugar may appear in the urine from the same cause.

Excretion.—Morphine is excreted mainly by the digestive tract, in the saliva, stomach and bowel, and is therefore found in large quantities in the fæces even after hypodermic injection. Traces of it occur also in the urine after large doses. It appears in the stomach very soon after injection; a weak reaction occurring after two and one-half minutes according to Alt, but after about an hour no further excretion into the stomach has been shown to occur, although its narcotic action persists much longer. A certain amount of the morphine undergoes partial oxidation in the tissues, and some oxidation products have been said to occur in the urine.

Tolerance.—The continued use of morphine or opium leads to a condition of tolerance, in which enormous doses of the drug are necessary to elicit any effect. Faust has succeeded in producing a similar state in dogs, and finds that much more morphine is oxidized in the tissues in this condition than in untreated animals; for when a normal dog received an injection of morphine, over 60 per cent. of the amount injected could be recovered from the stools, while when a much larger quantity was injected into a tolerant animal, none whatever was found in the excreta. The absence of symptoms from large doses in morphinists is not due wholly to the poison being oxidized before it can reach the brain, however, for Cloetta was able to isolate large quantities from the tissues of animals in which tolerance had been established. And while tolerance is easily acquired by some centres, others fail to develop it; thus dogs which have become so tolerant that even large amounts fail to induce narcosis, continue to react to even small quantities by slowing of the pulse; the cerebral nerve cells have become tolerant, but those of the vagus centre have failed to do so (Egmond); the bowel also continues to react to morphine as in the beginning (Myers). Some nerve cells thus become habituated to the presence of morphine in the blood and cease to react to it as strongly as in normal individuals, while others remain susceptible; in addition, the tissues

acquire a greater power of oxidizing morphine. In the rabbit no tolerance is developed even after prolonged treatment with morphine. Dogs which have been rendered tolerant to morphine are equally refractory to its allies, codeine and heroine. The attempt to find "antimorphine serum" has proved fruitless.

Codeine given in moderate quantities resembles morphine in its action in man but is much weaker. Thus one grain of codeine induces sleep and relieves pain in about the same degree as one-fourth grain of morphine; the sleep is said to be not so deep and restful as that which follows the administration of morphine, and the patient is liable to be awakened by slight noises, and is restless and often unrefreshed when he awakens. Somewhat larger quantities, instead of inducing deeper sleep, increase the restlessness and cause a considerable exaggeration in the reflex excitability. The respiration is slowed in the same way as by morphine but here again morphine is at least four times as powerful; large doses of codeine do not slow the respiration further. The pupil is slightly contracted during the codeine sleep, but dilates when the excitement stage follows. Codeine thus depresses the central nervous system in man, though there are indications of stimulation also when large quantities are used. In animals these symptoms of excitation are more obvious, however, especially in the spinal cord, in which the reflexes are rendered more acute and may finally give rise to spasms. In the cat morphine induces cerebral excitement, but under codeine this is often seen in the dog also and even to a slight extent in man.

Codeine acts less on the stomach and bowel than morphine, but when given in doses adequate to cause narcosis, it also causes constipation, and given along with morphine appears to intensify its action. It is excreted by the urine unchanged and none has been shown to undergo destruction in the tissues, as occurs in the case of morphine. No tolerance is acquired for codeine even after long use, and patients may in fact appear more susceptible to the drug, a dose which at first gave relief now causing nausea and vomiting. It is possible that this may indicate a tolerance of some parts of the central nervous system, which is not shared by the vomiting centre.

Codeine is methylmorphine, and a number of similar compounds have been formed artificially, such as ethylmorphine and amylmorphine. Two of these, ethylmorphine (**Dionine**) and benzylmorphine (**Peronine**) have been introduced into therapeutics, but appear to possess no advantages over codeine.

Oxydimorphine ($C_{34}H_{36}N_2O_6$) has been found in opium by some investigators, and has a very weak narcotic action resembling that of morphine.

Heroine, diacetylmorphine, is an artificial alkaloid formed from morphine by substituting acetyl for its two hydroxyls, and has attracted some attention recently through its being advocated as a respiratory sedative in cough. It appears to resemble morphine in its general effects, but acts more strongly on the respiration, and is therefore more poisonous. The action on the respiration is the same in kind as that of morphine, and the advantages claimed for heroine by its advocates have not been confirmed by impartial investigation. It appears to have rather more depressant effects on the cerebrum than codeine. In animals

large doses cause excitement and convulsions, and in man these have also been observed in cases of poisoning; the exhaustion from these convulsions is the cause of death in animals. Heroine is excreted mainly in the urine unchanged, but some is found in the stools. When it is given for some time, the tissues learn to destroy it and it no longer appears in the excretions. A certain tolerance is observed, for the narcotic action becomes less marked and may entirely disappear, but the exciting action of large doses remains unaffected (Langer). Many cases of heroine habit have occurred. On the whole the evidence of experimental and clinical observers seems to indicate that heroine deserves a place between morphine and codeine.

Thebaine seems to have practically no depressant action. It sometimes produces some heaviness and confusion in man, but this is accompanied by symptoms exactly resembling those described under strychnine, and it may therefore be considered as belonging to the latter series rather than to that of morphine; it is much less active than strychnine, however.

Papaverine stands midway between codeine and morphine in its action on the central nervous system, but is a comparatively weak poison. Even in large quantities it has not the soporific action of morphine, nor does it produce the same degree of excitement as codeine. Comparatively small quantities are followed by sleep and slow respiration, but this does not become deeper as the dose is increased. On the contrary, the reflex excitability is augmented, and after very large quantities some tetanic spasm may be elicited, but this seems to be of spinal origin entirely, while that produced by codeine points rather to an affection of the lower part of the brain. Papaverine has more tendency to slow the heart rhythm than morphine; it apparently acts directly on the heart muscle and a similar effect on the vessels dilates them when it is perfused through them; the blood-pressure is little affected by ordinary quantities, however. Papaverine is said to have a greater action in lessening peristalsis than the other alkaloids and, with he other isoquinoline alkaloids, relaxes the tone and shows the contractions of unstriated muscle and thus antagonizes morphine here; this is especially obvious in experiments on excised and suspended organs and is less distinct in the intact animal. It has not been shown that this action on organs containing unstriated muscle occurs in man.[1] Papaverine seems to undergo complete destruction in the tissues.

Narcotine resembles papaverine rather than morphine, but has even less depressant action, especially in mammals. In the frog a short stage of depression is elicited, but this soon gives place to strychnine-like exaggeration of the reflex excitability. In mammals there may be but little appearance of depression, the injection being followed by a condition of excitement immediately—restlessness and tremors with increased reflexes, which eventually lead to convulsions, during which the animal generally succumbs exactly as in strychnine poisoning. The pulse is considerably slower after narcotine injection, from a direct action of the drug on the heart. The sympathetic ganglia are first stimulated and then paralyzed, while the movements of unstriated muscle are affected in the same way as by papaverine. Narcotine is a much less poisonous body than either morphine or codeine, and very large quantities have been administered repeatedly with little or no narcotic effect. It is a compound of hydrocotarnine, another opium alkaloid, with opianic acid. **Hydrocotarnine** apparently acts very much in the same way as narcotine, but produces even less depression.

Narceine has little or no action of any kind. It is exceedingly insoluble in water, and its salts are broken up in aqueous solution, so that it is probably absorbed very slowly and imperfectly.

The other alkaloids occur in very minute quantities in opium and possess no great interest from the therapeutic point of view. Very little has been

[1] Macht attributes this action of the isoquinoline alkaloids to the benzyl group which they contain, and states that other benzyl derivatives have a similar depressant action on unstriated muscle.

done to elucidate their pharmacological action, but those which have been examined seem to produce effects resembling those of the better known members of the group. In frogs, small doses of **Cryptopine** and **Protopine** produce a narcotic condition similar to that following the injection of morphine, but the reflex irritability does not show the same exaggeration afterward; larger quantities cause complete paralysis of the whole central nervous system and partial paralysis of the terminations of the motor nerves, which gives rise to irregular contractions and relaxations of the muscles when the nerves are stimulated (Hale). In mammals, no depression occurs, but restlessness and eventually convulsions, which do not seem to be of spinal origin but rather suggest a stimulation of the cerebrum and midbrain. The heart is slow and weak, and some depression of the vaso-motor centres is caused by large quantities of the poisons. The respiration does not seem to be depressed, but rather to be accelerated, save by the largest doses. They paralyze the terminations of the sensory nerves on local application in the same way as cocaine. The action of these two alkaloids on the heart would seem to be further developments of the heart action noted after narcotine and papaverine.

In man morphine is much the most dangerous of the opium alkaloids, because death is produced in the narcotic stage through asphyxia. In most animals, however, thebaine, codeine and laudanine are more toxic, because the failure of the respiration does not occur in the stage of depression, but during the convulsions.

Opium itself contains, besides the alkaloids already discussed, various acids with which they are in combination, meconic, lactic, and sulphuric acid, but none of these possess any action of importance. Along with these are found gums, sugars, albumins, wax and the other common constituents of plant juices, but these merely tend to delay the absorption of the active constituents, and cannot be said to play any part in the effects of opium. Of the alkaloids, morphine is present in greatest abundance, and is also the most powerful in its effects on man. According to most observers the action of opium on the brain is practically identical with that of morphine, when due allowance is made for the slower absorption of the crude drug from the bowel; if any difference exists, it is so small as to be inappreciable in ordinary cases. But an old view that opium is a better narcotic than morphine has recently been resuscitated, and a preparation of all the alkaloids of opium without the other constituents has been introduced under the name of **Pantopon** (**omnopon**). This has not been shown to have more narcotic action than the morphine that it contains, and its composition varies considerably. According to Straub, the alleged superiority of opium over morphine as a narcotic is due to its containing narcotine, which in itself has comparatively little depressant power, but which intensifies that of morphine to a marked extent when they are administered together. He has therefore introduced morphine-narcotine meconate under the name of **Narcophine** as superior to morphine in narcotic power while less depressant to the respiration. Some later experiments seem to support Straub's view while others give the opposite result. Of late years a number of papers have been published purporting to show that one or other of the minor alkaloids strengthens the action of morphine in some direction, but no entirely convincing evidence has been

adduced and such statements are to be taken with reserve. As regards their action on the alimentary tract, opium and pantopon are practically identical, while morphine is less constipating; the greater sedative effect of opium and pantopon on the intestine may be due to the presence of papaverine (Zehbe), or codeine (Hesse), or to a slower absorption and more prolonged local action.

U. S. P. Preparations.

Opium, the air-dried milky exudation obtained by incising the unripe capsules of Papaver somniferum, yields when moist not less than 9.5 per cent. of anhydrous morphine. Dose, 0.1 G. (1½ grs.).

Opii Pulvis, dried and powdered opium, yielding 10 per cent. of anhydrous morphine. Dose, 0.06 G. (1 gr.).[1]

Extractum Opii, the dried aqueous extract, contains 20 per cent. of morphine. Dose, 0.03 G. (½ gr.).

Tinctura Opii (Laudanum) contains 10 per cent. of opium, or 1 per cent. of morphine. Dose, 0.5 mil (8 mins.).[2]

Pulvis Ipecacuanhæ et Opii (Dover's Powder), 10 per cent. each of opium and ipecacuanha powders. Dose, 0.5 G. (8 grs.).

Tinctura Opii Camphorata (Paregoric) contains four parts of opium per thousand, along with benzoic acid, camphor, oil of anise and glycerin. Dose, 4 mils (1 fl. dr.).[3]

Morphina ($C_{17}H_{19}NO_3+H_2O$), colorless crystals without odor but with a bitter taste, practically insoluble in water and only slightly soluble in alcohol. Dose, 0.008 G. (⅛ gr.)

Morphinæ Hydrochloridum.

Morphinæ Sulphas.

The hydrochloride and sulphate are soluble in about 15–17 parts of water, less so in alcohol. They form white, silky crystals with a bitter taste. Dose, 0.008 G. (⅛ gr.).

Codeina ($C_{18}H_{21}NO_3+H_2O$), white or nearly transparent crystals with a faintly bitter taste, soluble in 80 parts of water and in 1.6 parts of alcohol. Dose, 0.03 G. (½ gr.).

Codeinæ Phosphas, white needle-shaped crystals with a bitter taste, soluble in about 2 parts of water. Dose, 0.03 G. (½ gr.).

Diacetylmorphinæ Hydrochloridum ($C_{21}H_{23}O_5N.HCl+H_2O$), *Heroine*, a white crystalline powder soluble in 3 parts of water. Dose, 0.003 G. ($\frac{1}{20}$ gr.).

Æthylmorphinæ Hydrochloridum ($C_{19}H_{23}O_3N.HCl+2H_2O$), *Dionine*, a white or yellowish powder soluble in 8 parts of water. Dose, 0.015 G. (¼ gr.).

B. P. Preparations.

Opium, the juice obtained by incision from the unripe capsules of Papaver somniferum, inspissated by spontaneous evaporation. When dried it contains 9½–10½ per cent. of anhydrous morphine. Dose, ½–2 grs.

Extractum Opii Siccum contains 20 per cent. of morphine. Dose, ¼–1 gr.

Tinctura Opii, Laudanum, contains 1 per cent. of morphine, or about 1 gr. of opium in 10 mins. Dose, 5–15 mins. for repeated administration; for a single administration 20–30 mins.

[1] Practically identical forms are *Opium deodoratum* and *Opium granulatum*, each containing 10 per cent. of morphine. Dose, 0.06 G. (1 gr.).

[2] Another 10 per cent. tincture is *Tinctura Opii Deodorati*. Dose, 0.5 mil (8 mins.).

[3] An unimportant preparation is *Mistura Glycyrrhizæ Composita* (Brown Mixture), formed from liquorice, syrup, acacia, tartar emetic, spirit of nitrous ether and camphorated tincture of opium, and containing only about 1 part of opium in 2000. Dose, 10 mils (2½ fl. drs.).

Pilula Saponis Composita, contains 20 per cent. of opium. Dose, 2–4 grs.

Tinctura Camphoræ Composita, Paregoric[1] or Paregoric Elixir, contains camphor, benzoic acid, oil of anise and $\frac{1}{4}$ gr. of opium in each fl. dr. ($\frac{1}{10}$ per cent. of morphine. Dose, $\frac{1}{2}$–1 fl. dr.

Pulvis Ipecacuanhæ Compositus, Dover's Powder, contains 10 per cent. each of opium and ipecacuanha in powder. Dose, 5–15 gr

Pulvis Kino Compositus contains 5 per cent. of opium along with kino and cinnamon. Dose, 5–20 grs.

Pulvis Cretæ Aromaticus cum Opio contains $2\frac{1}{2}$ per cent. of opium along with aromatic chalk powder. Dose, 10–60 grs.

Pilula Plumbi cum Opio contains 12 per cent. of opium along with lead acetate. Dose, 2–4 grs.[2]

Morphinæ Hydrochloridum ($C_{17}H_{19}NO_3$,HCl,$3H_2O$), acicular prisms soluble in 24 parts of cold water, one part of boiling water, or 50 of alcohol. Dose, $\frac{1}{8}$–$\frac{1}{2}$ gr.

Morphinæ Tartras (($C_{17}H_{19}NO_3)_2C_4H_6O_6$,$3H_2O$), a white powder soluble in 11 parts of cold water, insoluble in alcohol. Dose, $\frac{1}{8}$–$\frac{1}{2}$ gr.

Liquor Morphinæ Hydrochloridi, 1 per cent., 10–60 mins.

Injectio Morphinæ Hypodermica contains $2\frac{1}{2}$ per cent. of the tartrate. Dose by subcutaneous injection, 5–10 mins.

Suppositoria Morphinæ,[3] each contains $\frac{1}{4}$ gr. of morphine hydrochloride.

Codeinæ Phosphas (($C_{17}H_{18}(CH_3)NO_3$,$H_3PO_4)_2$,$3H_2O$), white crystals with a slightly bitter taste, soluble in 4 parts of water, much less soluble in alcohol. Dose, $\frac{1}{4}$–1 gr.

Syrupus Codeinæ Phosphatis, one fluid drachm contains $\frac{1}{4}$ gr. of codeine phosphate. Dose, $\frac{1}{2}$–2 fl. drs.

Diamorphinæ Hydrochloridum, *Heroine* or diacetylmorphine hydrochloride, a white, crystalline powder having a bitter taste and soluble in 3 parts of water. Dose, $\frac{1}{25}$–$\frac{1}{8}$ gr

Therapeutic Uses.—Opium is one of the most important and most extensively used drugs in the pharmacopœias at the present day as in the past. Of late years the crude drug has been largely replaced by morphine, but the action is the same, and although morphine is preferable in most cases, opium is still specially indicated for certain purposes. In almost any disease, conditions which are favorably influenced by morphine may present themselves, and these conditions alone can be discussed here.

Pain.—As has been repeatedly mentioned, opium or morphine has a special analgesic action which is not shared by its modern rivals of the methane series, and which justifies the celebrated dictum of Sydenham[4] that without opium few would be callous enough to practise therapeutics. The general statement may suffice that severe pain

[1] Scotch Paregoric or *Tinctura Opii Ammoniata* contains ammonia, benzoic acid, oil of anise and nearly 5 grs. of opium in the fluid oz. (0.1 per cent. morphine). Dose, $\frac{1}{2}$–1 fl. dr.

[2] Other preparations of opium are *Pulvis Opii Compositus*, containing 10 per cent. of opium along with pepper, ginger, caraway, and tragacanth (dose, 5–15 grs.), and *Pilula Ipecacuanhæ cum Scilla* formed from Dover's powder and squills and containing 5 per cent. of opium. Dose, 4–8 grs.

[3] Other preparations containing morphine are the two lozenges, *Trochiscus Morphinæ* and *Trochiscus Morphinæ et Ipecacuanhæ*, each of which contains $\frac{1}{32}$ gr. of morphine, while the latter contains in addition $\frac{1}{10}$ gr. of ipecacuanha. Morphine is too powerful a drug to be dispensed in lozenges. The *Tinctura Chloroformi et Morphinæ Composita* (chlorodyne) contains one per cent. of morphine, chloroform, prussic acid, capsicum, cannabis indica, oil of peppermint, and glycerin, and is superfluous. Dose, 5–15 mins.

[4] Nollem esse medicus sine opio,

indicates opium. Even where the disease itself is one which would in ordinary circumstances contra-indicate it, it must always be taken into consideration whether the relief of the pain and its attendant restlessness may not counterbalance the disadvantages of the narcotic. At the same time the danger of inducing the craving for morphine cannot be forgotten, for the use of morphine to subdue pain is perhaps the most fruitful cause of the habit. It is often found that comparatively small quantities of opium are sufficient to remove or at any rate to dull pain, but after repeated doses the quantity has to be increased owing to tolerance being attained. Codeine may be used instead of morphine to allay pain, but has to be given in at least four times as large doses, and is ineffective in severe pain. Some forms of pain are relieved by the members of the antipyrine series, but these are less certain and more limited in their action than morphine. On the other hand the antipyretics often relieve pain without inducing sleep, and in this possess a great advantage over opium in the treatment of headache, neuralgia, and similar conditions.

Sleeplessness.—Opium was formerly the only drug used to induce sleep, but since the discovery of chloral and its congeners, it is used less frequently. These fail entirely to replace it, however, where the sleeplessness is due to pain, while, on the other hand, they are more efficacious in some conditions of excitement. Not infrequently opium and chloral are prescribed together for this purpose, and the combination acts more efficiently than either of the drugs alone. Each is, of course, prescribed in considerably smaller amount than if administered separately. Opium is less efficient than chloral when there is apparently an increased activity of the motor functions of the brain, as in wild delirium and mania, and sometimes seems to increase the excitement even, but this general statement is subject to numerous exceptions, and morphine is still largely used in many such disorders. In the true convulsive diseases, such as tetanus, epilepsy and chorea, chloral is preferable. In certain forms of motor excitation, especially in insanity, hyoscine is indicated as a sedative, and in cases of sleeplessness from anxiety and worry potassium bromide is generally preferred to any of the more powerful sedatives. The beneficial effect of morphine in many acute febrile conditions is undeniable, and, as in the case of alcohol, is due to its lessening the pain and discomfort of the patient and inducing rest. A good deal of difference of opinion exists as to the advisability of administering opium or morphine in these conditions, and there is no question that the routine treatment of fever by narcotics is to be deprecated; but on the other hand, restlessness and discomfort may in themselves aggravate the disease, and morphine is distinctly indicated under these circumstances.

The preparations chiefly used to relieve pain and promote sleep are the extract, laudanum, opium pill, or compound soap pill, and the morphine salts and their solutions, including the hypodermic injection.

In **Respiratory Disorders** opium and morphine are largely used for

their effects on the centre. Where it is desirable to lessen its irritability, as, for example, in excessive cough and dyspnœa, opium may be indicated. On the other hand, when there is a profuse expectoration, the irritability of the centre cannot be lowered without danger, and opium is contra-indicated. Opium gives relief in cases of asthma, but there is always danger of inducing the habit. In the rapid, shallow breathing of heart disease, the administration of opium or morphine is often followed by slow deep peaceful respiration without any reduction in the efficiency of the ventilation.

Opium is often combined with expectorants in the treatment of cough, and a number of suitable preparations are provided in the pharmacopœias, such as paregoric, Dover's powder and other preparations containing ipecacuanha, and codeine phosphate. The object of combining expectorants with opium is to allay excessive coughing; the opium reduces the excitability of the centre, while the expectorant causes a secretion of mucus in the respiratory passages and thus protects the irritated mucous membrane. The combination is indicated only in dry cough with little expectoration, and when there is abundant sputum to be removed by coughing the treatment may be harmful. Codeine is often preferred to morphine in these cases, because it reduces the excitability of the respiratory centre with less marked cerebral depression. Heroine and dionine were introduced as superior to codeine in this respect, but impartial investigators of these drugs have generally failed to obtain better results from them than from codeine and morphine.

In **Peritonitis and Intestinal Disorders** opium is indicated doubly; first, for its general action in allaying pain and restlessness; and secondly, for its special action in lessening the movement of the intestine. Opium is preferable to morphine for these purposes because it lies longer in the bowel, and therefore evolves a stronger action there than on the rest of the economy, and also because the minor alkaloids have some constipating effect. In colic, especially lead colic, it often relieves the pain without increasing the constipation and seems to allay the spasm of the bowel without stopping entirely its peristalsis. In diarrhœa opium may be given to check the excessive peristalsis, though in the severer forms of dysentery it generally fails to have this effect, and in septic purging is rather to be avoided. In perforation and hemorrhage from the bowel, opium is the most efficient of all remedies, as it allows adhesions or clots to be formed by checking movements of the intestine, which would provoke further leakage.

The B. P. offers a number of preparations specially designed for use in intestinal disorders and especially in diarrhœa, such as the compound kino powder, the compound chalk powder and the lead and opium pill. Instead of these the tincture, extract, or other simple preparation may be used.

In **Hæmorrhage,** where the bleeding point cannot be reached, opium or morphine is most valuable. This is not from any direct effect on the vessels or blood, but because it allays the restlessness which follows

the loss of large quantities of blood and thus allows the blood to clot in the ruptured vessel. The same preparations are suitable here as for pain.

In **Vomiting** morphine is sometimes used in small quantities, but it seems doubtful whether with any benefit.

Morphine is not infrequently given as a preliminary to general **Anæsthesia** in nervous patients ($\frac{1}{6}$ gr.), and in recent years operations have often been performed under morphine and hyoscine (scopolamine) alone. For this purpose $\frac{1}{6}$ gr. (10 mgs.) of morphine and about $\frac{1}{200}$ gr. (0.3 mg.) of hyoscine are injected an hour and a half before the operation, and again half an hour before it. The anæsthesia induced is often sufficient, and, if necessary, a few drops of ether or chloroform may be inhaled to complete it. The action of morphine and hyoscine on the brain is not synergistic, that is, the effects are not greater than the sum of the two alkaloids taken separately, as has often been stated. This narcosis has been used largely in labor, and with success ("twilight sleep"). It is sometimes stated to be dangerous to the child through depressing the respiratory centre, but this is disputed.

Opium has been used instead of quinine in **Malaria**, and though it cannot be said to replace the latter, has a distinct effect in some cases apparently. Of course, symptoms may arise in malaria as in other diseases in which opium is specially indicated, but apart from this, cases of malaria of old standing seem to be benefited by opium with or without quinine.

Opium or morphine has sometimes been used in **Diabetes** with good effects; for though the glycosuria seldom disappears under its use, it is lessened in some cases (Kaufmann). Codeine has been advised instead of morphine in this disorder, as it is less likely to cause constipation and gastric disturbance.

Lastly, opium is used as a **Diaphoretic,** and for this purpose it is generally combined with ipecacuanha and prescribed as Dover's powder. Although in itself it has little or no diaphoretic action, opium may augment the effects of ipecacuanha through dilating the skin vessels. Opium and its alkaloids have almost no effect applied to the skin, and the plasters, ointments and other similar preparations are obsolete.

Codeine is much less often used than morphine in therapeutics. It is of comparatively little value in allaying pain or excitement, but has been found of benefit in the sleeplessness of melancholia. It is used not infrequently as a sedative in cough, and, as has been stated, in diabetes. There is little or no tendency to form the codeine habit, and it has been suggested as a substitute for morphine in morphinomania, but has not proved efficient in this condition.

Opium and morphine are contra-indicated in children at the breast, in whom even minute quantities (*e. g.*, one drop of laudanum) may produce the most alarming symptoms of poisoning. After one year this special susceptibility seems to pass off and the dose of morphine has not to be reduced more than that of other drugs (Döbeli). In great weakness, especially in cases where the respiration is barely

sufficient to aërate the blood, or where profuse expectoration is present, morphine has to be administered with the greatest care. In cerebral congestion and meningitis the opiates are generally contra-indicated. It must be remembered also that both opium and morphine are liable to disturb the digestion and to cause nausea and want of appetite, and that these may prevent their use in cases in which they would otherwise be suitable. In some persons opium invariably causes nausea and vomiting, either soon after its administration or while its effects are passing off. For this idiosyncrasy morphine may be substituted for opium, although this is often equally nauseating, or chloral and bromides may be prescribed with opium to prevent the unpleasant after-effects. In all chronic painful diseases opium or morphine has to be given guardedly, on account of the risk of the formation of the opium habit; the patient ought to be kept in ignorance of the drug used as far as possible, and it should be alternated with others. Of course, in cases of incurable, hopeless disease, where life can only last a comparatively short time and is attended by severe suffering, this objection does not hold, and it may be necessary to administer morphine without stint and in ever-increasing quantity.

Morphine and opium are often said to be contra-indicated in Bright's disease of the kidney. This seems to be due to the belief that morphine is excreted in the urine, which has now been shown to be erroneous. There seems no reason to believe that morphine is harmful in these conditions, and in some forms of uræmia it has even been of considerable benefit.

Acute Poisoning with morphine or opium is one of the commonest forms of intoxication, with the exception of the alcoholic. It is often difficult to diagnose from other forms of unconsciousness, but the extreme contraction of the pupils gives a clue, as a general rule, and if opium has been used, the breath often has the characteristic odor.

The treatment of acute morphine or opium poisoning should consist in removing the poison from the body and in guarding against failure of the respiration.

The first object is best attained by washing out the stomach with the stomach tube, as emetics generally fail when morphine has been absorbed owing to the depression of the centre. Even when morphine has been injected hypodermically, gastric lavage may have some value as some of the poison is excreted into the stomach. Water should be used to wash out the stomach; dilute potassium permanganate solution has been advised, but tends to oxidize the gastric mucous membrane rather than the morphine. A sharp purge may be given to remove the morphine excreted into the bowel and also to promote excretion by irritating the mucous membrane.

In morphine poisoning the danger is failure of the respiratory centre. This may be combated by the use of respiratory stimulants of which the best is caffeine (often given in the form of hot coffee). Strychnine has also an antagonistic action to morphine and may be injected. And

atropine has been used to increase the excitability and appears to be of value in small quantities; but not more than $\frac{1}{40}$ grain should be used as larger amounts tend to weaken the respiration. Caffeine is safer and is at least as efficacious in arousing the depressed centre.

Besides increasing the excitability of the centre by these drugs, the normal stimulus may be augmented. Thus respiration may be aroused reflexly from the skin by dashing cold water on it, or by irritating it with the electric current, or by flicking it with wet cloths. But the chief normal stimulus of the respiratory centre is the carbonic acid of the blood, and an attempt should be made to increase this and thus to promote the aëration. This may be attained by keeping the patient in motion as far as is possible, in order that the muscles may supply CO_2, but as this may have to be done for several hours, it entails great fatigue both for patient and attendant. A more rational method of enriching the blood with CO_2 would be to allow the patient to breathe air containing 7–10 per cent. of the gas, which might be kept in readiness in the hospitals where opium poisoning is often encountered.

Finally, if the respiration fails in spite of these measures, artificial respiration must be employed and continued as long as the heart beats. Cases of recovery from enormous doses of morphine are recorded in which artificial respiration was maintained for many hours.

Chronic Opium or Morphine Poisoning is a not infrequent condition, and, unfortunately, seems to be increasing rapidly. Among Eastern nations, especially in China, opium is smoked, and some of the morphine is carried over in the smoke and absorbed from the respiratory tract. This habit is rare in European peoples, among whom the drug is taken by the mouth, generally in the form of laudanum or of pills, or is injected hypodermically as morphine hydrochloride or sulphate. Of the three methods the first seems to be the least harmful, for in some parts of China the majority of the adult population seems to indulge in it without the serious results which are met with in the Western opium-eaters and morphinomaniacs. This result may be due in part to race, or to the fact that the opium-smoker never attains to the immense doses taken daily in the cases of the habit met with in Europe and America. In the beginning the quantity used is small, but as tolerance is attained, ever larger quantities are required to produce any effect, until, as De Quincy states in his "Confessions of an Opium-eater," 320 grains of opium may be required to stay the craving. The effects are generally described as stimulant, but it seems possible that they consist rather in depression of the sensibility, by which the unfortunate patient becomes unconscious of the miseries of his condition, and may accordingly be able to perform his duties and maintain appearances better than when deprived of the poison. The symptoms of the opium habit are exceedingly indefinite, and the diagnosis is often almost impossible. The statements of the patient ought not to be taken into consideration, because these unfortunates seem to have lost all idea of honor and truthfulness. As a general rule they are nervous, weak in character and wanting in energy, and utterly unfit for work unless when sup-

plied with the drug. The pupils are often contracted, the heart sometimes irregular, and tremors and unsteadiness in walking may be apparent. The appetite is bad and a considerable loss in weight occurs, and the movements of the bowels are irregular, constipation alternating with diarrhœa. Eventually melancholia and dementia may follow the prolonged use of opium, and especially of morphine. Some continue the habit for many years, however, and it would seem with comparative immunity. If morphine is injected habitually, evidence may be obtained from the small needle marks on the front of the body, which often give rise to multiple abscesses of small size from carelessness in the disinfection of the syringe. When other evidence fails, it may be necessary to give a moderate dose disguised in some unusual way and to observe if it induces sleep; in habitual users the ordinary dose will have little or no effect.

The treatment of chronic morphine poisoning is not very promising. The will and self-control would seem completely paralyzed in many cases, and although the patient wishes to be freed from his enemy, he seems utterly unable to withstand the craving. The only means of treatment which promises success in most cases is the strict regime of an asylum or retreat, where the patient is kept under constant supervision. The immediate removal of the drug often produces such intense misery and depression as to seem actually dangerous; but the withdrawal ought not to be too gradual, and ought to be complete after two or three weeks at the most. The patient has to be watched carefully for long after he has apparently recovered, as relapses are exceedingly common.

The morphine habit has often been combated by the substitution of other drugs, such as cocaine, but the result generally has been that a new and even more dangerous habit has been substituted for, or often merely grafted on, the original. Numerous drugs have been proposed for the cure of morphinomania, but none of them seems to have the slightest effect.

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Minor Drugs of the Opium Series.

In some other members of the poppy family (Papaveraceæ), alkaloids are found which bear a close resemblance to those of opium. These are *Chelidonine*, *α-*, *β-* and *γ-Homochelidonine*, *Chelerythrine* and *Sanguinarine; Protopine* is also found in a number of other papaveraceæ. These alkaloids are met with in very small quantities in various plants, of which Sanguinaria Canadensis (Bloodroot) and Chelidonium majus (Celandine) are the best known.

Chelidonine and *α-homochelidonine* produce moderate depression of the central nervous system and narcosis. In the frog no secondary increase in the reflex irritability follows, but in some mammals a slight stimulation of the spinal cord may be caused. They have the same effect as papaverine on muscle and heart, and like it produce insensibility of the skin and cornea when applied locally, through paralyzing the terminations of the sensory nerves. The heart is slower through direct action on the cardiac muscle. The respiration is slightly slowed and deepened. Chelidonine has been advised in the treatment of colic and asthma in view of its depressant action on unstriated muscle. (Dose 0.1–0.2 G.)

Sanguinarine has very little depressant action, but causes tetanus and wild excitement, so that as far as its action on the central nervous system is concerned, it deserves a place between codeine and thebaine of the morphine series. It possesses the same peripheral action as protopine, however, and the heart is slowed through direct affection of the muscle. Sanguinarine paralyzes the peripheral sensory endings when applied locally, but this paralysis is preceded by a stage of irritation. It causes violent peristalsis of the bowel, and increases the secretion of saliva.

β-homochelidonine resembles protopine and cryptopine closely in its effects, causing the same stimulation of the lower parts of the brain with very slight effects on the intellectual powers, slowing the heart through its muscular action and paralyzing the sensory terminations.

Chelerythrine paralyzes the central nervous system without any preliminary increase in the reflex irritability, possesses the peripheral action of protopine and cryptopine, and first irritates, and then paralyzes the sensory terminations.

None of the plants containing these alkaloids have been used to any great extent, although Sanguinaria Canadensis was formerly occasionally prescribed as a nauseating expectorant and emetic.

Anhalonium.—A number of alkaloids, some resembling morphine, others like strychnine in their effects on animals, have been isolated from dif-

ferent members of the Anhalonium genus (Fam. Cactaceæ). In Mexico, and along the southern boundary of the United States, where those plants are indigenous, some of them are used as narcotics in the religious rites of the Indians and are known as Pellote, Peyotl, or Muscale or Mezcal Buttons. The symptoms arise for the most part from the cerebrum and differ from those of opium and cannabis indica in the frequency with which color visions are induced, these consisting in constantly shifting flashes of brilliant tints. Mezcal eating does not induce merriment like cannabis nor sleep like morphine, but depression of some functions is indicated by the imperfect coördination of the movements, the retarded perception, and the errors in the estimation of time. The exaltation seems to be caused for the most part by one of the alkaloids, mezcaline. Very large doses have induced unpleasant symptoms through depression of the respiration. Anhalonium and pellotine, one of its alkaloids, have been used as narcotics in a few cases of insomnia.

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III. CANNABIS.

The hemp plant possesses no pharmacological interest when grown in temperate regions, but when cultivated in warm climates as in India, Egypt or the southern United States, it develops products which induce marked derangement of the central nervous system. The Indian plant was formerly supposed to be a distinct species, but differs so little from the European form that botanists now consider them merely varieties. The old name of Cannabis Indica has, however, been retained in medicine. Its introduction into Western medicine dates only from the beginning of last century, but it has been used as an intoxicant in Asiatic countries and in Africa since unknown time, and under the names of *Hashish, Bhang, Ganja, Charas* or *Churrus,* is habitually indulged in by some one or two hundred millions of mankind. Some of the preparations are smoked either alone or mixed with tobacco; others form an intoxicating drink, while in others it is mixed with sugar or honey and taken as a confection.

The active principle of Indian hemp has been found by Wood, Spivey and Easterfield to be a red oil or resin boiling at a high temperature, which they term *Cannabinol;* this was found by Marshall to induce the typical effects of cannabis in man and animals. Fränkel states that cannabinol is a phenolaldehyde of the formula $OH.C_{20}H_{28}COH$.

Symptoms.—The effects of cannabis indica are chiefly due to the changes in the central nervous system, in which it induces a mixture of depression and stimulation similar to that seen under small doses of morphine. Its action is much less constant, however, and seems to depend very largely on the disposition and intellectual activity of the

individual. The preparations used also vary considerably in strength, and the activity of even the crude drug seems to depend very largely on the climate and season in which it is grown, so that great discrepancies occur in the accounts of its effects. Soon after its administration, the patient passes into a dreamy, semi-conscious state, in which the judgment seems to be lost, while the imagination is untrammeled by its usual restraints. The dreams assume the vividness of visions, are of boundless extravagance, and, of course, vary with the character and pursuits of the individual. In the eastern races they seem generally to partake of an amorous nature. The true believer sees the gardens of paradise and finds himself surrounded by troops of houris of unspeakable beauty, while the less imaginative European finds himself unaccountably happy and feels constrained to active movement, often of a purposeless and even absurd character. Ideas flash through the mind without apparent continuity, and all measurement of time and space is lost. True hallucinations may appear, but are often absent, the chief features of the action being merriment, comfort, well-being, and self-satisfaction. Often less pleasant thoughts obtrude themselves, however, such as the fear of impending death or of some imminent, indefinite danger. During this period the consciousness is not entirely lost, for the patient often feels that his dreams are unreal, his satisfaction unfounded and his movements ridiculous, but he cannot restrain them; he can give a coherent account of his condition when aroused and answers questions intelligently. The sensation of pain is lessened or entirely absent, and the sense of touch is less acute than normally. Later the dreams alternate with periods of complete unconsciousness, from which the patient can be aroused easily, and the symptoms eventually pass into tranquil sleep, from which he awakens refreshed, and, as a rule, without any feeling of depression or nausea. In the majority of cases the preliminary stage of exaltation is very short or entirely absent in Europeans, the first effects of the drug often being heaviness, drowsiness, noises in the ears and numbness of the extremities, which pass into deep sleep. According to Dixon, the drug is much more exhilarating when inhaled than when swallowed, and this may account for some of the variations in its action. In some cases, acute mania and convulsive attacks have been developed, and among the natives of India catalepsy occasionally occurs.

In animals the effects of cannabis indica seem to resemble those in man and present the same marked variations; a stage of exaltation with increased movement is sometimes present and is followed by depression, lassitude, and sleep. The reflex excitability is first increased and then diminished in frogs. Vomiting is often induced in dogs and cats, but cannabis indica differs from opium in producing no disturbance of the digestion and no constipation. The heart is generally accelerated in man when the drug is inhaled; the intravenous injection in animals slows the pulse partly through inhibitory stimulation and partly through direct action on the heart muscle. This action on the heart is stated by Dixon to be the cause of death after poisonous

quantities, for he found the respiration persist for some seconds after standstill of the heart. The pupil is generally somewhat dilated. Polyuria is stated to occur in dogs, in which cannabinol appears to be excreted by the kidneys in combination with glycuronic acid (Fränkel).

Death from acute poisoning is extremely rare, and recovery has occurred after enormous doses. The continued abuse of hashish in the East sometimes leads to mania and dementia, but does not cause the same disturbance of nutrition as opium, and the habitual use of small quantities, which is almost universal in some Eastern peoples, does not seem detrimental to them, although among Europeans it might possibly be as fatal as that of morphine. Some tolerance is rapidly acquired.

Preparations.

Cannabis (U. S. P., B. P.), Indian hemp, the flowering tops of the female plant of Cannabis sativa (hemp).

Extractum Cannabis (U. S. P., B. P.), 0.01 G. ($\frac{1}{6}$ gr.); B. P., $\frac{1}{4}$–1 gr.

Tinctura Cannabis Indicæ (U. S. P., B. P.), 0.75 mil (12 mins.); B. P., 5–15 mins.

The preparations vary extremely in strength and many are entirely inert, especially when they have been kept some time. The U. S. P. requires them to be tested biologically. (See p. 43.)

Therapeutic Uses.—Cannabis indica is used as a hypnotic in cases of sleeplessness from nervous exhaustion and, less often, from pain. It is not nearly so reliable as opium, and in fact produces sleep in only about 50 per cent. of the cases, according to some authors. On the other hand, it does not disturb the digestion and produces no subsequent nausea and depression, and may therefore be employed in some cases in which opium is contra-indicated. It is of use in some cases of migraine, and has been prescribed as a substitute for opium in mental diseases.

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IV. BROMIDES.

It was formerly widely believed that the bromides had no further action than the chlorides, and that any effects observed from potassium bromide were due to the potassium ion, the bromide ion being indifferent. There is now no question, however, that the bromides have distinctive effects, for all bromides induce changes in the central nervous system, which are not elicited by the chlorides. The bromide of potassium is the salt most generally used.

Symptoms.—The local action on the alimentary tract is the same as that of sodium chloride and other salts; the bromides have a bitter salt taste and induce salivation and thirst, and in large quantities

irritation of the stomach, nausea, and vomiting. Ocasionally diarrhœa has been observed from concentrated solutions reaching the intestine.

General Symptoms.—Apart from these results of local irritation, the first symptom is often a dull, heavy headache, with a feeling of lassitude, fatigue, disinclination for exertion, mental or physical, and often muscular weakness. Thought is slow and confused, the memory is indistinct, ideas are put into words with difficulty and the speech is accordingly slow and hesitating. External objects and movements are perceived, but arouse no interest in the patient, and very often this state of apathy passes into drowsiness and sleep. The bromides, however, have not the sleep-compelling power of morphine or chloral, and the sleep is never very deep and is not refreshing, the patient sometimes feeling dull and unfit for exertion after it, and some mental confusion often persisting for several hours after waking. The reflexes are much depressed by large doses of bromide, so that touching the back of the throat does not induce nausea, although the sensation of touch may persist. The mucous membranes of the genito-urinary tract are also less sensitive, or rather their irritation is less liable to set up reflex movements. After very large doses of the bromides the conjunctiva may sometimes be touched without causing winking, and lessened sensation in the skin has been noted in some cases. The pulse and respiration are slower than usual after large doses, but scarcely more so than in sleep. An increase in the urine is often observed.

Acute fatal poisoning with bromides has seldom or never occurred in man, but after enormous doses prolonged sleep or stupor has been seen, and confusion and apathy lasting for several days.

When bromide is given repeatedly in large doses, a series of symptoms is often induced to which the name of **Bromism** has been applied. It occurs much more rapidly in some persons than in others, and may suddenly appear after the patient has been taking the drug for months without any untoward results. The commonest symptoms of bromism are *skin eruptions* of various kinds, very often commencing as acne of the face. In severe cases the pustules of acne may coalesce and form small abscesses, which are followed by ulcers. In other cases the skin affection partakes rather of the nature of a localized blush or erythema and sometimes copper-colored blotches have been observed. Some *disturbance of the digestion* and loss of appetite is often met with from the local action of large quantities of the salt on the stomach. Affections of the *respiratory passages* are not produced so often by the bromides as by the iodides, but have been met with, and consist in an increased secretion of mucus by the bronchial and nasal epithelium. The *mental symptoms* are merely exaggerations of those observed after one large dose. The memory is especially defective, sometimes sudden lapses occurring, sometimes a general inability to remember the most recent events being met with. The patient is indifferent to his surroundings, speaks slowly and stammers, mispronounces ordinary words or misses several words out of a sentence. The gait is uncertain and

tremor often accompanies any movement, the expression of the face is stupid and apathetic, and the eyes are heavy and lack lustre.

These symptoms generally disappear on the withdrawal of the drug, but in his reduced condition the patient is liable to fall a victim to infectious disease, and in a number of cases of chronic bromide poisoning the immediate cause of death has been an attack of bronchitis or pneumonia.

Action.—The effects of the bromides on animals can be examined only by the use of sodium bromide, as when the potassium salt is used, the action is complicated by the presence of potassium effects, which are often sufficient to obscure the slight depression of the brain which is the really characteristic effect of the bromide ion. In the frog, for example, potassium chloride is capable of inducing depression of the central nervous system, and the slightly greater depression induced by the bromide may well be overlooked; it appears, however, that bromides have very little true depressant action on the frog. The typical bromide action may be induced with greater clearness in mammals by the use of sodium bromide in repeated doses, and in dogs symptoms of depression and imperfect coördination have been observed, and sometimes stupor and death from failure of the respiration; the symptoms of central nervous depression can be elicited by a single large dose in the guinea-pig — lethargy, incoördination of movements, deep sleep passing into coma and often ending in death. The most characteristic action, however, is obtained from the administration of the drug to patients, as the affection of the central nervous system is so slight after all but extreme doses, that in order to produce distinct symptoms in the less sensitive animals, quantities must be used which entail the additional complications induced by salt-action.

Fig. 15

A case of bromide acne in a child.

The irritation of the throat and stomach, the nausea, vomiting and rarer diarrhœa must be attributed for the most part to the action of the salt in withdrawing fluid from the mucous membranes, and may be avoided by the use of dilute solutions and by their administration when the stomach is full.

The depression and other mental symptoms are due to a direct action on the **Central Nervous System.** Albertoni found that the irritability of the motor areas of the dog's brain was very distinctly reduced by the administration of bromides, and in particular that a

stimulus which normally would have spread over a wide area and given rise to an epileptiform convulsion, caused only localized contractions after bromides, while convulsive poisons entirely failed to act. Loewald found some psychical processes, such as those involved in the addition of numbers, uninfluenced by bromides, while a series of figures could be learned by rote only with great difficulty; he therefore considers that the action is limited to certain definite functions. The reflexes are also reduced very considerably by bromides, and according to many observers the passage of impulses from the sensory to the motor cells of the cord is interrupted, while the connection between the cerebral centres and the motor cells of the cord is maintained intact. In man the most striking instance is the absence of reflex nausea when the back of the throat is touched. While reflex movements cannot be elicited, the sensation often remains unimpaired, but after large doses a more or less complete anæsthesia is said to be produced. This anæsthesia extends to the skin when very large quantities are administered, and the cutaneous sensation is said to be blunted when comparatively small doses are taken; the action is purely central, the peripheral sense organs remaining unaffected.

The respiration is slower under bromides, owing to the lessened movement, but is scarcely more reduced than in normal sleep. The sexual instincts are depressed or entirely suspended, either from the action on the brain or from the lessened reflex activity.

The bromide ion is almost as indifferent to most of the tissues as the chloride; for example, muscle and nerve live almost as long in solutions of sodium bromide as in those of the chloride of equivalent concentration. The heart may be perfused with saline containing bromide instead of chloride for many hours and is only slightly affected. When bromides are given by the mouth, the heart is not affected; potassium bromide injected intravenously in animals is poisonous to the heart as are the other potassium salts, but potassium bromide taken by the mouth has no effect on the heart. The vessels of the pia mater have been observed to be contracted under the bromides, but not more than in normal sleep, and this anæmia of the brain is the result, not the cause of the depression. The temperature is often reduced in animals under bromides from the lessened movement and consequent lessened production of heat.

The skin eruptions arise in the great majority of cases from the glands, and in fact generally remain confined to them. Bromide has been found in the acne pustules, but the old view that the acne is due to bromine being freed in the glands is undoubtedly incorrect.

Distribution and Excretion.—The bromides are rapidly absorbed by the mucous membranes, and some bromide reaction can be obtained from the urine a few minutes after they have reached the stomach. Their distribution in the body resembles exactly that of the chloride; thus they are found in largest amounts in the blood plasma and have little tendency to accumulate in the organs. They occur in all the secretions and fluids of the body; they may be found in the form of

hydrobromic acid in the stomach, and traces are found in the sweat and milk and in the hair, where chloride occurs naturally. The brain and spinal cord do not contain larger quantities than the other organs and never approach the amount contained in the blood plasma; the skin appears to contain a larger amount than most other organs.

The whole behavior of the bromides in the body indicates that most of the tissues are unable to differentiate them from the normal chloride ions, and react to a dose of bromide in the same way as to one of common salt. Thus the administration of bromide is followed by the excretion of an equivalent amount of salt, but the kidney does not discriminate between the two forms circulating in the blood but eliminates a mixture of chloride and bromide exactly in the same proportion as these occur in the blood. If it were possible to follow the course of the individual ions in the body after a dose of common salt, it would probably be found that although an equivalent amount of salt is soon eliminated in the urine, the actual chloride ions taken would only be represented in this excretion to a limited extent, the rest being furnished by that previously present in the blood and tissues; the remaining new chloride would gradually be eliminated in diminishing proportions. This is what occurs in the nearly related bromides; at first the amount excreted bears a high proportion to that of the chloride, but this falls off rapidly and some bromide appears in the urine for long afterward. Thus, after a single dose of 30 grs. the urine was found to contain bromide for two months, only about 10 per cent. being eliminated in the first twenty-four hours. When the treatment is continued, the bromide therefore tends to accumulate in the body, but the proportion excreted rises with the increase of the salt in the blood, until an equilibrium is reached, exactly as much bromide appearing in the urine as is absorbed from the bowel. The excretion then continues long after the treatment is discontinued.

When the body is thus saturated with bromide, the blood plasma and all the fluids may contain as much bromide as chloride; for example, the gastric juice may contain even more hydrobromic acid than hydrochloric acid. The bromides are not simply added to the normal salts of the blood, but supplant the chlorides, which are excreted in quantity, so that the normal salt concentration of the blood is maintained, though the chloride is much diminished. During bromide treatment, therefore, and especially in bromism, not only is there an excess of bromide in the body, but also a deficiency of chlorides, and it has been much discussed whether the symptoms of bromism and the sedative effects of bromide arise from the action of the bromide directly, or are the results of the deficiency of chloride. In favor of the latter view, it is urged that the bromide action is elicited more readily when the chloride of the food is lessened, and that the addition of chloride to the dietary often relieves the symptoms of bromism and on the other hand restores the epileptic seizures which have disappeared under bromide treatment. And Loeb finds that certain fish are depressed in bromide solution but remain normal if chloride is added. But all

of these observations may be explained by the acknowledged fact that the administration of chloride promotes the excretion of bromide and thus lessens the concentration of bromide in the fluids of the body. And on the other hand it is found that animals may be narcotized with bromide quite rapidly, long before it is possible that a serious fall in the chlorides of the blood has occurred. So that the bromides appear to possess a definite action on the nerve cells, quite apart from the deficiency in chlorides. In practice, however, the bromide action is accompanied by chloride poverty and on the other hand any excess of chloride reduces the concentration of bromide and thus interferes with the treatment. The same is true of other measures which tend to withdraw bromide, such as the use of diuretics.

The bromides of sodium, potassium and ammonium have identical effects in man when given by the mouth. In animals when they are injected intravenously, the potassium and ammonium bromides may present in addition the action of the potassium and ammonium ions.

Preparations.

Potassii Bromidum (U. S. P., B. P.) (KBr),
Sodii Bromidum (U. S. P., B. P.) (NaBr),
Ammonii Bromidum (U. S. P., B. P.) (NH_4Br),
} 1 G. (15 grs.); B. P., 5–30 grs.

The bromides are all colorless crystalline bodies without odor but with a saline, bitter taste, and are very soluble in water. They are almost always prescribed in solution, which may be flavored with some aromatic syrup; they are not given hypodermically owing to the large dose necessary.

A number of other bromide combinations are used in therapeutics, such as the hydrobromide of quinine, but here the bromide ion is present in very small quantity compared with the alkaloid, and in the doses used in therapeutics has no appreciable effect. In monobromated camphor the bromine is present in a different form and no bromide ion is liberated, and the bromine in this compound seems to have little or no effect. *Sabromine*, the dibrombehenate of calcium ($(C_{22}H_{41}O_2Br_2)_2Ca$), has been introduced as a substitute for the alkali salts, but differs from them in being stored in the fatty tissues and in only slowly freeing the bromide ion. It has not been proved to be of value. *Bromipin* and *Bromeigon* and other bromine compounds have not proved equal to the bromides in practice. Strontium bromide and hydrobromic acid are quite superfluous.

Therapeutic Uses.—The bromides are used chiefly in the treatment of epilepsy, in which they cannot be replaced by any other drug, and the prognosis of which has been entirely changed since their introduction. In a few cases the bromide treatment is said to cure epilepsy—the attacks do not return after the treatment is stopped—but this is exceedingly rare; in others the bromides have no effect, but in the great majority of cases (90–95 per cent.) the number of attacks is much smaller, or the patient may be entirely free from them as long as the treatment is persevered with, although they return as soon as it is given up. In one large epileptic colony it was found that when no bromide was given the number of fits per patient averaged 13.3 per month, but this fell to 1.5 per month under treatment with moderate doses of bromide and no symptoms of bromism were seen; larger doses

did not reduce the average of attacks further, but caused mental dulness and acne. Very often no improvement is observed during the first few days, until the tissues have become saturated with bromide, but in other cases the spasms disappear immediately. In severe cases it is sometimes found that the bromide action is strengthened by the addition of cannabis indica, opium or chloral, although the last two are to be used with caution. In the treatment of epilepsy it is well to begin with small doses and to increase them up to 10 G. per day, or until the desired effect is attained, or some complication, such as widespread skin affections, precludes their further use.

When little chloride is taken in the food, the excretion of bromide is much retarded, and, on the other hand, the addition of chloride to the dietary accelerates the bromide excretion. The restriction of the salt in the food of epileptics under bromide treatment has therefore been suggested with the object of saturating the tissues with smaller doses of bromide than would otherwise be necessary. In practice, however, it is difficult to reduce materially the chlorides of the food, and equally satisfactory results may be obtained, with less hardship to the patient, by slightly increasing the dose of bromide. The use of bromide has to be continued for many months or years in epilepsy and the aim should be to reduce the dose to the lowest efficient one and to maintain this without variation. It may also be useful to keep the chloride of the food fairly constant and to avoid any treatment which may disturb the concentration of bromide in the blood, such as diuresis or violent purgation.

The acne is often a troublesome accompaniment of the bromide action, and in fact may prevent the use of this valuable drug in otherwise suitable cases. It may often be prevented by scrupulous cleanliness of the skin, and sometimes yields to treatment with small doses of arsenic.

The bromides are not so effective in other affections of the central nervous system, although some success has attended their use in chorea, in the convulsions of children, and in some forms of hysteria. They have also been used in tetanus and in strychnine poisoning, but are inferior to other remedies, such as chloral. Neuralgia is sometimes improved by bromide treatment, especially when it arises from worry, anxiety, or overwork.

As soporifics, bromides often fail entirely, or induce such depression and confusion subsequently as to preclude their use. This prolonged action doubtless arises from the slow excretion of the bromide, the great proportion of that taken remaining in the tissues for more than twenty-four hours. In sleeplessness from anxiety they are often valuable, however, and it is found that the dose of chloral may be considerably lessened if it is prescribed along with bromides. In sleeplessness from pain bromide is of little or no value. The bromides are little suited for use in a single dose unless it be a large one. On the other hand their prolonged action is very valuable in cases of exaltation and nervousness in which it is desired to allay the excitability without causing actual sleep, and in which an immediate effect is not so necessary as a prolonged slight action.

Bromides have been used with good results in sea-sickness, in the sickness of pregnancy, and, it is said, in whooping cough.

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V. STRYCHNINE—NUX VOMICA.

Strychnine is the chief alkaloid occurring in several species of Strychnos, of which the best known are Strychnos nux vomica and Strychnos Ignatia. It is found chiefly in the seeds, and is generally accompanied by the nearly related alkaloid *Brucine.*

A large number of alkaloids have been found to resemble strychnine in their action, such as the *Thebaine* found in opium, and the *Gelsemine* of Gelsemium sempervirens, while it is difficult to decide whether several others ought to be classed with morphine or with strychnine

Strychnine seems to be a quinoline derivative, although its exact constitution is unknown. Its formula is $C_{21}H_{22}N_2O_2$, while that of brucine is $C_{23}H_{26}N_2O_4$. They are both derivatives of a substance of the formula $C_{15}H_{17}N_2O_2$, brucine differing from strychnine in having two methoxyl groups. It seems not unlikely that they are both nearly related to curarine, the alkaloid of curara, which is derived from some other species of the genus Strychnos.

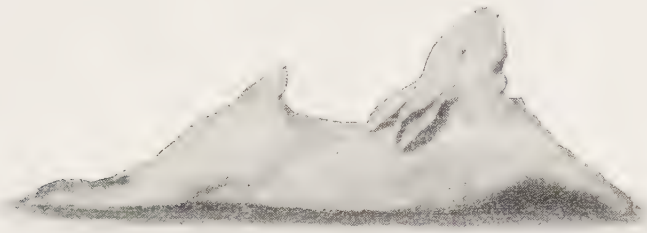
The alkaloids of the strychnine group have a powerful stimulant action on the central nervous system, especially on the spinal cord, throughout the vertebrate kingdom.

Symptoms.—In ordinary therapeutic doses strychnine, like other bitter substances (page 55), improves the appetite and often leads to a distinct amelioration of the subjective symptoms, the patient feeling stronger and more hopeful. The special senses are rendered more acute by small quantities of strychnine, for differences can be recognized between shades of color which seem identical to the normal vision; the field of vision is widened, and in certain conditions of amblyopia light is rendered much more distinct. In the same way the hearing seems to be more acute, and the sense of touch is more delicate. Some cases have been noted in which disagreeable odors were rendered pleasant by strychnine, but this would seem to be a rare idiosyncrasy. In larger doses strychnine increases the reflex movements, and the sense of touch is rendered distinctly more acute.

In cases of poisoning with strychnine, these effects are present but

are not generally observed by the patient, whose first complaint is of a feeling of stiffness in the muscles of the neck and face. This is soon followed by an increased reflex reaction, so that a slight touch causes a violent movement, and even a sound or a current of air is sufficient to cause a sudden start. The increased reflex irritability is generally accompanied by some restlessness, and animals sometimes seem to make attempts to escape from bright light. Some tremor or involuntary

FIG. 16



A rabbit during a strychnine convulsion.

twitches may be observed in the limbs, and then a sudden convulsion occurs in which all the muscles of the body are involved, but in which the stronger extensor muscles generally prevail. In animals the head is drawn back, the hind limbs extended, and the trunk forms an arch with its concavity backward (opisthotonos) (Fig. 16). In man the same convulsions are seen and are accompanied by strong contraction of the face muscles, producing a hideous grin which has been called

FIG. 17

A rabbit when the strychnine spasm is passing off. The head is supported to prevent it falling on the table.

the *risus sardonicus*. The respiratory muscles are involved in the general paroxysm and the blood rapidly becomes deoxygenated, as is shown by the blue, cyanotic color of the lips and face in man. The muscles feel hard and firm at the commencement of the convulsion, but very soon a tremor may be made out, which becomes more distinct, and after a few intermittent contractions the animal sinks back in a condition of prostration (Fig. 17). The respiration generally returns,

and becomes fairly regular for a short time. Immediately after a convulsion the reflex irritability may be low, but it soon regains its former exaggerated condition and a second convulsion occurs, exactly resembling the first. Mammals, as a general rule, succumb after two or three convulsions, the respiration failing to return after the spasm. In some cases, however, the convulsions become shorter and the intervals of quiescence longer, the respiration becomes weak, the reflex irritability gradually lessens and the animal dies from asphyxia. In frogs, where the breathing can be dispensed with for long periods, the alternation of convulsions and periods of quiescence may continue for hours or days, but these are of the same general character as those described in mammals. After very large quantities no convulsions may occur, the animal dying almost immediately of asphyxia from paralysis of the central nervous system.

Action.—The whole character of the intoxication points to an affection of the **Central Nervous System,** and it has been found that the symptoms are unaltered when the drug is prevented from reaching the peripheral nerves and muscles. The chief symptoms arise from the spinal cord, for the convulsions are at least as well marked in frogs and mammals in which the brain has been destroyed or severed below the medulla oblongata. The intellect in man remains unclouded until the end, except for the asphyxia produced by the stoppage of the respiration; the patient is perfectly conscious of his condition, and suffers excruciating pain from the violent contractions of the muscles.

The special senses are rendered more acute by small doses of strychnine, and this is apparently due to its effects on the central nervous system in the case of touch, taste and smell, but there is reason to believe that the increase in the field of vision and the increased sensitiveness to slight differences in light are to be attributed to its acting on the cells of the retina and not to cerebral changes. For when strychnine salts are injected in the temple or applied to the conjunctiva, the sight of the corresponding eye is improved while the other remains unaffected (Filehne); if the strychnine acted centrally it could do so only by being carried to the brain by the blood, but this would affect each hemisphere equally. The affection of one eye only is explained by the strychnine diffusing through the lymph spaces, and this is said to have occurred in the case of various dyes which were applied in the same way and were then found in the retina.

Ergographic experiments have shown that small doses of strychnine augment the capacity for muscular work, and delay the onset of fatigue; this excitation phase is followed by one in which the capacity is lowered. Electrical stimulation of the motor areas of the brain is more effective under strychnine than in unpoisoned animals, but this does not necessarily indicate that the cells of these areas are acted on directly, for the same apparent increased irritability of the cortical areas is seen when the poison acts on the cord only, and it may therefore be the result of the spinal action.

The convulsions are, as has been stated, of spinal origin.[1] It has been shown that in the frog they are reflex, that provided no stimulus reaches the cord from without, no convulsion occurs. As has been already remarked, the convulsions are preceded by a stage of increased reflex, and in fact the first convulsion is often seen to follow a stimulus, such as a blow or a loud noise. Afterwards they may seem to occur without any such impulse, but this is merely because a very slight or even imperceptible stimulus is enough to induce them. For example, a slight contraction of a muscle may induce a convulsion, as is seen very frequently in the frog, where a very slight stimulus, in itself apparently too weak to cause a convulsion, is followed by an ordinary reflex contraction, and this leads to a spasm. The absence of convulsions when external stimuli are cut off may, however, be demonstrated conclusively in various ways. Thus Poulsson found that a frog dipped in cocaine solution undergoes no convulsions after strychnine, the cocaine used being sufficient to paralyze the sensory terminations, but not to have any direct effect on the cord. Claude Bernard showed this even more conclusively by dividing all the posterior roots of the spinal nerves in the frog and then injecting strychnine, when no convulsions occurred except when the ends of the cut roots were stimulated. In mammals, however, it appears that even when all external impulses are excluded by section and degeneration of the posterior roots, convulsions still occur from strychnine; here apparently the excitability of the neurons in the cord is so extreme that they originate spasms without any impulse from without, while in the frog the advent of an external stimulus is necessary. But even in the mammal the spasms generally occur from some touch or sound or other disturbing factor.

The characteristic feature of strychnine poisoning is thus the changed response to external stimuli. In the unpoisoned animal the simple reflex movement following a stimulus is coördinated and purposive; for example if the leg of a decapitated frog be dipped in acid it makes certain movements to withdraw the limb, and no matter how often the irritation be repeated, the same movements are produced, though it is true that if stronger acid be used the movement is more violent and a greater number of muscles are involved. In this movement certain muscles contract while their antagonists are inhibited; thus in drawing the toe away from an irritant the anterior muscles of the leg contract, while the gastrocnemius is relaxed. Under strychnine this simple reflex is stronger and is elicited by weaker irritation, and this change persists during poisoning if the external stimulus is weak and acts slowly. When a stronger or more sudden shock is applied to a poisoned animal, the response is quite different; all the muscles contract together, there being no inhibition of antagonists, and the resultant movement has thus quite a different character; the gastrocnemius being stronger than the anterior leg muscles, the foot is extended and thrust against the irritant instead of being withdrawn from it. And not only the muscles concerned in the

[1] In this term is included not only the spinal cord proper, but also those parts of the brain which correspond to the cord in performing simple reflex movements.

simple reflex, but those of the whole body are involved in the movement. This tetanic contraction of all the muscles may arise from an external stimulus which is no stronger than is required to induce a simple reflex in the unpoisoned animal. The response is the same whether the stimulus is derived from the periphery and the consequent movement is a reflex one, or from the brain. In both cases the change in the character of the movement arises from changes in the spinal cord, the impulse from the brain or periphery bearing its normal character, but changing its nature in passing through the cord.

It is often stated that this convulsive movement is a changed normal reflex, that under strychnine the spinal cord has lost its power of coördinating movement and can only respond to afferent impulses by efferent motor impulses to all the muscles. This is erroneous, however, for each form of response may be elicited alternately in poisoning; a weak stimulus is followed by a strong but coördinated purposive simple reflex, while a stronger one throws the body into general tetanus. This is not a development of the simple reflex, but is a totally different movement which is akin to the violent movement which occurs in normal persons and animals when a sudden unexpected touch or sound arouses them; here also the whole of the muscles contract together, there being no inhibition, and the resulting movement is determined by their relative strength; in man the powerful extensors of the trunk produce a violent straightening and the subject is said to "jump out of his chair." Strychnine lowers the threshold of the stimulus of this response, so that it is elicited by ordinary touch or weak sounds and becomes the response characteristic of the poisoning.

When an external stimulus is sufficient to cause this convulsive movement in a poisoned animal, the contraction is always maximal; a stronger stimulus produces no greater effect.

Houghton and Muirhead and later Baglioni stated that the cells of the anterior horn are not necessarily involved in the strychnine action. For when strychnine is applied in solution to the cord of the frog at the level of the cells connected with the nerves to the fore limbs, irritation of the hind foot produces an ordinary response in the hind limbs, while the anterior part of the body remains motionless; that is, strychnine has not penetrated to the cells connected with the hind limbs. Irritation of the fore limbs, on the other hand, produces tetanus not only of these, but also of the hind limbs, although the motor cells of the hind limbs have been shown to be outside the poisoned area. Tetanus can, therefore, be produced in parts whose motor cells are unpoisoned. The increased strength of the contraction is due, not to augmented energy in the anterior horn cell, but to the impulses which these receive being much stronger. But later investigators (Ryan, McGuigan, Barenne) state that this experiment does not hold in mammals, in which there is less chance of the results being confused by diffusion than in the small cord of the frog, and bring forward further evidence that tetanus can be induced only when the poison acts both on the motor anterior horn cells and on the sensory part of the reflex arc; the attempt to localize the action outside the motor cells cannot be regarded as successful in the light of these researches, unless the experiments on which it is based are supported by further work. All are agreed that the posterior root ganglion is not the seat of action, for convulsions may be elicited by stimulation of the posterior roots above this point. It is possible that the chief seat of action is in the synapses of the neurons intercalated between those of the posterior root and the nerve cells of the anterior horn.

An impulse travelling up a nerve in an unpoisoned frog reaches the cord and may there pass through a number of paths and in each is subjected to various influences, so that it arouses different motor cells to different degrees of activity, or actually inhibits the activity of some of them; in this way a coördinated movement follows. Under strychnine these influences, which may be figured as varying resistances in the different paths, disappear, and the impulse passes untrammeled along all available paths and reaches the motor cells in much greater force than normally and thus arouses a more powerful reaction from them and a correspondingly strong muscular contraction. But the resistance in the different paths is essential to coördinate the movement and the increased muscular contraction is thus no longer coördinated, all the muscles contracting together and the character of the movement being determined by their relative strength. The action of strychnine may thus be explained by supposing that it removes resistances to the passages of impulses through the spinal cord and thus extends the area on which an impulse acts, and also liberates it from the normal coördinating influences.

It must be remarked that while the resistance is much reduced, it is not entirely removed, and the ordinary path is still somewhat more easily traversed than the others, for weak irritation causes an ordinary reflex response in the frog, while a slightly stronger stimulus throws it into opisthotonos. In this condition a whole series of discharges occurs of longer duration than the simple reflex, and this without any further impulses reaching the cord either from without or from the muscles and joints involved in the movement; for when all movement is excluded by curara, the electrical changes can be observed in the cord corresponding to the muscular spasms in the convulsions.

Besides the spinal cord, all other regions in which simple reflexes can be produced, are affected by strychnine. Thus the medullary centres are thrown into the same condition, and their responses to stimuli are equally exaggerated; but they are in constant receipt of impulses, and strychnine, by increasing the efficiency of these, augments the tone of the medulla oblongata, when it is given in small quantities.

Artificial respiration has been shown to delay the onset of convulsions in animals, but it is still an open question whether this is due to the better aëration of the blood (Osterwald) or to the effects of the mechanical movements (Gies and Meltzer).

The stimulation of the spinal cord by strychnine is followed by depression and paralysis. Even during the first stage the stimulation is mixed with depression, for though a more violent response is induced by a sensory stimulus, this cannot be repeated so often as in the normal frog, as the cord becomes fatigued more readily. The sensory part of the spinal cord seems to be paralyzed somewhat earlier than the motor cells, but these also lose their irritability after a time and no further movement can be elicited either by reflex or by direct stimulation of the cord.

Strychnine seems to have no direct action on the voluntary Muscles;

it is stated that minute quantities increase their tone, that is, render them more tense, so that they are prepared for immediate contraction, but this is due to action on the cord and not on the muscle fibres.

The **Terminations of the Motor Nerves** are paralyzed by large doses of strychnine in the same way as by curara. This effect is scarcely seen in mammals, as central paralysis always precedes it and destroys life, but in some species of frogs the nerve ends are paralyzed before the central nervous system. This paralysis is not due to the exhaustion

FIG. 18

Tracings of the blood-pressure (upper) and intestinal volume (lower) from a curarized cat, showing the effect of the intravenous injection of a dose of strychnine sufficient to cause spasms in an uncurarized animal. The blood-pressure rises, while the mesenteric vessels are contracted from spasm of the vasomotor centre (Bayliss).

of the nerve ends through the tetanus, but is a direct action on the terminations, although the exhaustion may contribute to the result.

The **Respiration** is quickened by small quantities of strychnine, especially when the centre is depressed by the previous administration of a narcotic. During the convulsions the breathing is arrested by the violent contractions of the diaphragm and the other respiratory muscles, but during the intermissions it continues fairly regular. After one or two spasms it often fails to be reinstated, and the animal dies of asphyxia; in other experiments it undergoes a gradual diminution in rate and

strength, and eventually ceases from gradual paralysis of the centre. A reversal of the respiratory reflexes is sometimes seen after large doses in animals and is analogous to that described in the inhibitory reflexes of the spinal cord.

The **Heart** is not directly affected by strychnine in mammals, though it is sometimes slightly slowed by stimulation of the inhibitory centre. During and after a convulsion it may be accelerated as in violent exertion from any cause. Very large quantities slow and weaken the frog's heart.

The **Vasomotor Centres** in the medulla oblongata and the cord are often stimulated by small quantities, so that the splanchnic vessels are constricted, while the cutaneous and perhaps the muscular vessels tend to dilate from stimulation of the vasodilator centre. The blood is thus deflected to some extent from the internal organs to the skin and limbs. Larger quantities tend to disorganize the vasomotor centre in a way analogous to that described in the spinal cord, for Bayliss finds that inhibitory reflexes involving the vasomotor centre are changed to motor ones; thus stimulation of the depressor nerve after strychnine causes a rise in blood-pressure.

During the convulsions the blood-pressure is raised to an extreme height, partly owing to the activity of the vasomotor centre and perhaps partly from the blood being pressed out of the abdominal organs and the muscles by the violent contractions. Immediately after a convulsion the blood-pressure falls, probably from the exhaustion of the centre.

In the **Alimentary Tract,** strychnine has the same action as any other bitter substance, and it produces a flow of saliva and increased appetite if taken before meals. (See Stomachic Bitters, page 55). It seems to be absorbed from the intestine mainly. After absorption it is said to increase the movements of the bowel from some action on the muscle or on the ganglionic plexus in the bowel wall.

Metabolism.—Strychnine produces an enormous activity of the muscles, and, therefore, increases very greatly the consumption of oxygen and the output of carbonic acid. This is accompanied by an increased formation of heat, which would lead to a rise in the temperature of the body were it not counteracted by an equal or even greater increase in its dissipation through the skin. As a result the temperature is generally lowered in rabbits, while it sometimes rises slightly in dogs and cats. The skin temperature, on the other hand, rises considerably because more blood flows through it than usual.

Glycosuria occurs in frogs and in young mammals, and the glycogen of the liver and muscles disappears in most animals under strychnine; the increased muscular movement and the disturbance of the respiration are probably the explanation of both of these phenomena.

Strychnine is absorbed rapidly and is distributed equally in the red corpuscles and plasma of the blood. In man from 10 to 20 per cent. of that ingested reappears in the urine, in which the reaction begins after about three hours and remains from three to eight days. The rest of the

alkaloid is taken up by the liver and undergoes oxidation. Only a very slight degree of tolerance is developed for strychnine, even after very prolonged administration.

The action of strychnine is almost identical throughout the vertebrate kingdom. Man is more susceptible than other mammals, and young animals are more refractory than adults, perhaps owing to the less developed condition of the central nervous system. The domestic fowl tolerates comparatively large quantities without symptoms. The convulsant action is seen in some of the higher invertebrates, in the lower it induces paralysis only.

Brucine, the second alkaloid of nux vomica, resembles strychnine closely in action but is much weaker, from 30 to 40 times as large a dose being required to produce the same effect. It differs from strychnine also in possessing a more powerful action on the nerve terminations in voluntary muscle, especially in some species of frog. It is credited with weak local anæsthetic properties.

Preparations.

Nux Vomica (U. S. P., B. P.), the seeds of Strychnos nux vomica, contains not less than 2.5 per cent. of total alkaloid (U. S. P.) (1.25 per cent. of strychnine, B. P.) and tannin, which gives a dark green coloration with iron salts. Dose 0.06 G. (1 gr.); B. P., 1–4 grs. The preparations are assayed to a definite strength of strychnine in the B. P., of total alkaloids in the U. S. P.

Extractum Nucis Vomicæ (U. S. P., 16 per cent. total alkaloids), 0.015 G. ($\frac{1}{4}$ gr.); (B. P.), 5 per cent. strychnine, $\frac{1}{4}$–1 gr.

Tinctura Nucis Vomicæ (U. S. P., 0.25 per cent. total alkaloids), (B. P., 0.125 per cent. strychnine), 0.5 mil. (8 mins.); B. P., 5–15 mins.

Strychninæ Nitras (U. S. P.), 0.0015 G. ($\frac{1}{40}$ gr.).

Strychninæ Hydrochloridum (B. P.), $\frac{1}{60}$–$\frac{1}{15}$ gr.

Liquor Strychninæ Hydrochloridi (B. P.) (1 per cent.), 2–8 mins.

Injectio Strychninæ Hypodermica (B. P.) (0.75 per cent. of the hydrochloride), 5–10 mins. hypodermically.

The extract is generally prescribed in pill form, while strychnine nitrate or hydrochloride may be given in solution, pill or tablet; where rapid action is desired, it is injected subcutaneously. A number of unnecessary preparations containing strychnine and iron and quinine are contained in the pharmacopœias, which also mention a *fluidextract* (U. S. P., 2.5 per cent.), and a *liquid extract* (B. P., 1.5 per cent.).

Therapeutic Uses.—Strychnine is used largely for its local action on the digestive organs as a stomachic bitter, and is generally prescribed in the form of the tincture or the extract for this purpose, as in this way it is less rapidly absorbed than when given as an alkaloidal salt. It may be combined with the cinchona preparations or with one of the simple bitters.

Small quantities of strychnine are of benefit in many ill-defined conditions of weakness, cachexia, and "want of tone" generally. The results are probably partly due to its stomachic effects in increasing appetite and digestion, but the action on the central nervous system cannot be overlooked. The slight increase in the irritability of the cord probably leads to an improvement in almost all of the nutritive functions through increasing the contraction of the vessels and producing greater activity of the muscles. In this way strychnine per-

haps deserves the name of "tonic" more than most of the drugs to which it is applied.

As a stimulant to the central nervous system strychnine has found wide application in almost every form of paralysis, and as long as distinct anatomical lesions of the central nervous axis are absent, it may be of benefit; for instance, it is often valuable in lead poisoning; but where the continuity of the axis is broken by hæmorrhage or by the destruction of the nerve cells, little improvement is to be anticipated from its use, though it may serve to delay or prevent the atrophy of peripheral nerves and muscles in some of these cases. When the paralysis is due to an inflammatory process, strychnine is to be used with the greatest care, or is perhaps better avoided entirely as long as the irritation is present, as it seems to increase and prolong the inflammation when used early in these cases. The other central nervous stimulants, such as caffeine or atropine, have not been employed in these forms of paralysis.

Strychnine is used as a respiratory stimulant in some forms of pulmonary disease in which it is desirable to increase the respiration or to provoke coughing. It has been advised in failure of the respiration during anæsthesia, and is certainly more likely to be beneficial than the great majority of drugs suggested for this purpose. Too large doses must not be injected in these cases, however, as strychnine paralyzes the respiratory centre itself when given in excess. In other forms of poisoning in which the respiratory centre seems in danger, and in shock, strychnine may also be of service, especially when it is injected hypodermically. Other respiratory stimulants which may be substituted for strychnine for these purposes are caffeine and atropine.

In amaurosis or amblyopia unassociated with atrophy of the optic nerve, and even in commencing atrophy, strychnine has frequently improved the vision. In many cases it fails to produce any benefit, and the exact conditions in which improvement can be looked for are unknown.

Strychnine has been used in heart disease, but all exact observations agree that it has no beneficial action (Parkinson and Rowlands). In weakness of the circulation from inefficiency of the vasomotor centre it may act, though Crile denies it any value in the treatment of the low blood-pressure of shock, and Cabot could not find any change in the blood-pressure after its use in a number of conditions in which it is ordinarily advised. Cook and Briggs found the blood-pressure increased in certain cases of vasomotor paresis, however, when $\frac{1}{60}$–$\frac{1}{10}$ gr. of strychnine was injected hypodermically. In rare cases this weakness of the medullary centre simulates heart disease, and this may account for the belief in the virtues of strychnine as a cardiac tonic.

Strychnine is said to be of value in chronic alcoholism in lessening the depression which forms one of the chief difficulties in the treatment.

Poisoning.—In cases of strychnine poisoning, the first treatment consists in the evacuation of the stomach by means of emetics, or, better, by the stomach tube; it may be necessary to give chloroform, as

the attempt to pass the tube is often followed by violent convulsions. Preparations of tannic acid, such as strong tea, may be given in order to form the insoluble tannate, which, however, must be removed as quickly as possible, as it is broken up by the acid gastric juice and the strychnine is rapidly absorbed. Others have advised the administration of charcoal in fine powder in order to absorb the strychnine and prevent its passage into the blood. To combat the convulsions, depressants to the central nervous system should be given, and, although chloral is usually advised, chloroform or ether is often preferable. It is unnecessary to produce deep anæsthesia, a few whiffs of chloroform being often sufficient to allay the convulsions. The advantage of the anæsthetics over chloral is that they can be removed if any symptoms of strychnine paralysis appear. Opium has been suggested, but is not nearly so efficacious in strychnine poisoning as members of the methane series. If the paralysis comes on, artificial respiration may be attempted, although the poison is destroyed too slowly by the organism to permit of much hope of recovery.

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In addition, strychnine was studied by Magendie, Cl. Bernard, and Orfila.

VI. PICROTOXIN.

Picrotoxin is the best known member of a group of convulsive poisons, which resemble each other very closely in action, but of whose chemistry little is known beyond the fact that they are devoid of nitrogen. It is obtained from the Anamirta paniculata (Anamirta cocculus, Menispermum cocculus), and is a neutral indifferent body. Picrotoxin ($C_{30}H_{34}O_{13}$) may be broken up into picrotoxinin ($C_{15}H_{16}O_6$), which resembles it in its effects on animals, and picrotin $C_{15}H_{18}O_7$), which is inactive.

Other poisons resembling picrotoxin are *Cicutoxin*, derived from the Cicuta virosa, or water hemlock, and probably from other species of Cicuta, *Œnanthotoxin*, the active principle of Œnanthe crocata, water dropwort, or dead tongue, and *Coriamyrtin*, which occurs in several species of Coriaria, of which

the best known is the Coriaria myrtifolia or currier's sumach; *Tutin*, the active principle of the toot or tutu poison of New Zealand, is obtained from other species of coriaria. Some of these bodies are glucosides. *Camphor* and some other volatile oil derivatives, notably the *Thujon* of absinthe, also resemble picrotoxin in their effects, and the same is true of two alkaloids *Samandarine* and *Samandaridine* isolated by Faust from the skin of the newt. Lastly, some poisonous substances inducing symptoms like those of picrotoxin have been formed by the decomposition of the glucosides of the digitalis series.

Symptoms.—The symptoms, which are often somewhat late in appearing, are very similar in all classes of vertebrates. In man vomiting is not infrequently observed, or the first symptoms may be salivation, acceleration of the respiration, and some slowness and palpitation of the heart. Stupor and unconsciousness follow and then a series of powerful convulsions, which, commencing in tonic spasms, soon change to clonic movements of the limbs, which are alternately extended and flexed in contrast with the prolonged contraction under strychnine. The respiration is interrupted during these spasms, but is reinstated during the intervals of quiet and collapse which follow them. The convulsions return after a short pause, and this alteration of spasm and quiet may continue for some time, although the respiration often fails to return after one of the spasms, and fatal asphyxia results.

Similar effects are observed in the lower mammals. After a preliminary stage in which twitching of the muscles and vomiting often occur, and in which the respiration is accelerated, while the pulse is slow, a violent emprosthotonic convulsion sets in, but soon changes to clonic movements; these may last for some time, but eventually become weaker and give place to a condition of quite and depression. An increase in the reflex excitability is noticeable during this interval, the animal is easily startled and occasional twitching of the muscles may be observed. Very soon a second convulsion sets in, and this may be fatal from asphyxia, but the symptoms often continue for an hour or more, violent spasms alternating with periods of depression and collapse. In the frog clonic convulsions are also the chief feature of the intoxication. Very often the animal becomes distended with air during the convulsions, and gives a curious cry in releasing it. The heart is always slowed and may cease to beat altogether for a time.

Action.—The clonic convulsions of picrotoxin poisoning are different from those of strychnine and other similar bodies, which induce prolonged tonic convulsions, and it was early surmised that the members of this series act on a different part of the **Central Nervous System.** In the fish convulsions arise from picrotoxin after all the nervous system has been removed except the spinal cord. In the frog they persist when all of the brain above the medulla oblongata has been removed, although they are weaker after destruction of the optic lobes; on the other hand, they lose their typical character when the medulla oblongata is removed. In mammals, the convulsions are less typical when the cerebral hemispheres are removed and disappear when the pons is destroyed. The seat of action thus seems to move upward as the higher parts of the central nervous system become more developed, the chief effects arising from the spinal cord and medulla and optic lobes in the frog and from the cerebrum and midbrain in mammals. It is possible that in man the cerebrum is even more involved in the action than in the lower mammals. In Toot poisoning in man, it is often observed that a confused mental condition is present and that the memory is impaired after the attack and for some days later.

The stimulation of the medulla is seen in the acceleration of the respiration, in the slow pulse, which is due to inhibitory action, in a very marked rise of the blood-pressure, and in the vomiting and salivation. In many animals the reflexes are found to be increased when the medulla is severed from the cord, and this indicates that the spinal cord is also more excitable than normally. Grünwald suggests that the centres controlling the cranial and sacral autonomic nerves are especially susceptible to the action of these poisons.

The action of picrotoxin is confined to the central nervous system and nothing is known of its distribution and fate in the body. Like other convulsive poisons, it tends to lower the temperature when it is given in quantities insufficient to cause convulsions.

The convulsions of picrotoxin and its allies disappear when chloroform or chloral is administered. On the other hand, the respiration, weakened by narcotic poisons such as chloral, is accelerated by picrotoxin, the blood-pressure rises, and the sleep is less prolonged. Animals are not awakened at once from narcosis by picrotoxin, but coriamyrtin has this effect. Picrotoxin is not antidotal in morphine poisoning in animals, but may possibly be so in man.

Therapeutic Uses. –It has been proposed to give picrotoxin and coriamyrtin by subcutaneous injection in cases of collapse and in narcotic poisoning, but it has not been employed for this purpose in therapeutics as yet. It has some reputation in the profuse night-sweats of phthisis, which it diminishes in a certain proportion of cases, probably by increasing the respiration and thus preventing the stimulation of the nervous mechanism of perspiration through the partial asphyxia. Dose, $\frac{1}{60}$–$\frac{1}{20}$ gr. in pill or tablet.

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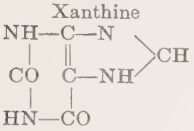
VII. CAFFEINE.

In a number of plants used in different parts of the world to form beverages and condiments, there are found the xanthine compounds, *Caffeine, Theobromine* and *Theophylline* (*Theocine*), which have been employed in therapeutics of late years, and have, therefore, acquired a double importance as drugs and as articles of diet. The widespread use of preparations of these by uncivilized peoples is a curious and unexplained fact, especially as they possess neither peculiar taste nor odor to guide in the selection of the plants in which they exist. Besides, caffeine and its allies in moderate quantities induce no marked symptoms, such as follow the use of alcohol, opium or hashish and explain their use among widely separated peoples. On the contrary, the only effects to be observed are a brightening of the intellectual faculties and an increased capacity for mental and physical work. Coffee, the use of which is derived from the Arabians, is the berry of Coffea Arabica and contains caffeine; tea, the leaves of Thea Chinensis, contains caffeine along with theophylline. Cacao, cocoa, or chocolate is derived from the seeds of Theobroma cacao, a tree indigenous in Brazil and Central America and contains theobromine. In central Africa, the Cola or Kola nut (Sterculia acuminata) is used by the natives, and contains caffeine with small quantities of theobromine. In Brazil, Guarana paste is formed from the seeds of Paullinia sor-

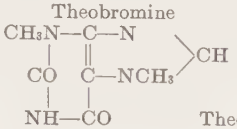
bilis, and contains caffeine and theobromine, while in the Argentine Republic, Yerba Mate or Paraguay tea (Ilex Paraguayensis) is used to form a beverage which contains a small quantity of caffeine. Another species of Ilex is met with in Virginia and Carolina under the name of Apalache tea or Youpon, and also contains caffeine.

These three principles, caffeine, theobromine and theophylline, are purine derivatives closely related to the xanthine bodies found in the urine and tissues of animals; theobromine and theophyllin are dimethylxanthine and caffeine is trimethylxanthine.

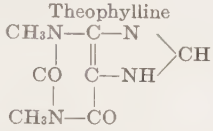
Xanthine



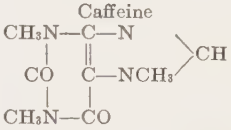
Theobromine



Theophylline



Caffeine



Action.—These all resemble each other in most points of their pharmacological action, although caffeine acts on the central nervous system as well as on the kidneys, muscle and heart, while theobromine has comparatively little effect except on the last three.

Central Nervous System.—In man, caffeine stimulates the central nervous system, in particular that part associated with the psychical functions. The ideas become clearer, thought flows more easily and rapidly, and fatigue and drowsiness disappear. Not infrequently, however, connected thought is rendered more difficult, for impressions follow each other so rapidly that the attention is distracted, and it requires more and more effort to limit it to a single object. If the quantity ingested is small, however, the results are of distinct benefit in intellectual work. The capacity for physical exertion is also augmented, as has been demonstrated repeatedly by soldiers on the march, and more recently by more exact experiments with the ergograph. The stimulation of the higher nervous centres is often manifested in the insomnia and restlessness which in many people follow indulgence in coffee or tea late at night. Kraepelin has investigated the effects of caffeine from the psychological point of view, and finds that both tea and coffee facilitate the reception of sensory impressions and also the association of ideas, especially in fatigue, while the transformation of intellectual conceptions into actual movements is retarded. This he regards as due to stimulation of the highest or controlling functions of the brain, caffeine acting on the same parts as are first affected by alcohol and the methane derivatives, but altering them in the opposite direction. The effect of caffeine on the acuteness of the senses has been demonstrated by the greater accuracy of touch under its influence.

Large quantities of caffeine often cause headache and some confusion, and in rare cases of special susceptibility a mild form of delirium may be elicited, or noises in the ears and flashes of light may indicate derange-

ment of the special senses. The pulse is quickened, and occasionally palpitation and uneasiness in the region of the heart are complained of. Convulsive movements of the muscles of the hand, and tremor in different parts of the body have also been recorded in some cases. These effects are induced only with difficulty in habitual drinkers of tea or coffee, so that the continued administration of small quantities of caffeine evidently gives rise to tolerance.

In the lower mammals the injection of large quantities of caffeine is followed by symptoms closely resembling those induced by strychnine. The reflex irritability is remarkably increased, the lightest touch being followed by powerful contraction of almost all the muscles of the body. After a time these contractions occur without any apparent stimulus, and culminate in tonic convulsions which last for several seconds. During these, the respiration ceases because the respiratory muscles are involved in the spasm, and occasionally it fails to be reinstated when the convulsions pass off. In other instances the spasms become weaker and occur at longer intervals; the respiration diminishes in frequency and depth and eventually ceases.

The symptoms induced by caffeine in the lower mammals are due for the most part to its acting on the spinal cord in the same way as strychnine, though small doses may act on the brain, for they often elicit restlessness and timidity without any marked change in the reflex excitability. The centres in the medulla oblongata are also involved in the effects, as is indicated by acceleration of the breathing and occasionally by some slowness of the pulse from action on the pneumogastric centre.

Frogs show no nervous symptoms that cannot be ascribed to action on the spinal cord, and in some species these are elicited with considerable difficulty owing to the muscular action described below.

On comparing the effects of caffeine and strychnine on the central nervous system, it will be found that while there is a general similarity in their action, the latter causes more marked stimulation of the lower divisions and has less action on the cerebrum in mammals and man. They both produce a general increase in the activity of nerve cells, but caffeine acts more on the psychical, strychnine more on the reflex functions.

Theophylline resembles caffeine in its action on the central nervous system, while theobromine induces few or no symptoms of stimulation. The monomethyl-xanthines and xanthine itself stimulate the central nervous system in the frog (Schmiedeberg).

The **Muscular** action of caffeine is best seen in the Rana temporaria (grass frog), although it is also induced in other species of frogs; it is less obvious in mammalian muscle and appears to be absent in invertebrates. When a few drops of caffeine solution are injected into the leg of a frog there follows a peculiar stiffness and hardness in the muscles around the point of injection, which slowly spreads to other parts of the body and induces the appearance of rigor mortis. The same effect is observed when teased muscle fibres are subjected to a caffeine solution under a high-power microscope. The fibres contract, become white and opaque, and

look stiff and inflexible; the transverse striæ disappear, while the longitudinal become more easily visible (Fig. 19). This appearance is due to the death and rigor mortis of the fibres, in which the myogen is formed into myogen-fibrin apparently; the same change occurs when caffeine is added to myogen in the test-tube.

In small quantities caffeine increases the irritability of muscle as well as its absolute strength and extensibility; that is, the muscle contracts on a weaker stimulus and against a greater load than it does normally. The amount of work done before fatigue sets in is also increased, unless when large quantities are applied, when the capacity for work is lessened; and with the first appearance of rigor it ceases to react to stimuli altogether. Sobieranski has stated that in ordinary doses caffeine increases the work done by the human muscles when they are stimulated by electric shocks. The universally recognized effect of tea and coffee in increasing the capacity for physical work and in relieving fatigue has generally been regarded as due to changes in the nerve cells, and it does not seem likely that the action on the

FIG. 19

A muscular fibre of the frog (highly magnified). *A*, normal; *B*, after the application of caffeine solution. The coarse striæ in *B* are the folds of the sarcolemma.

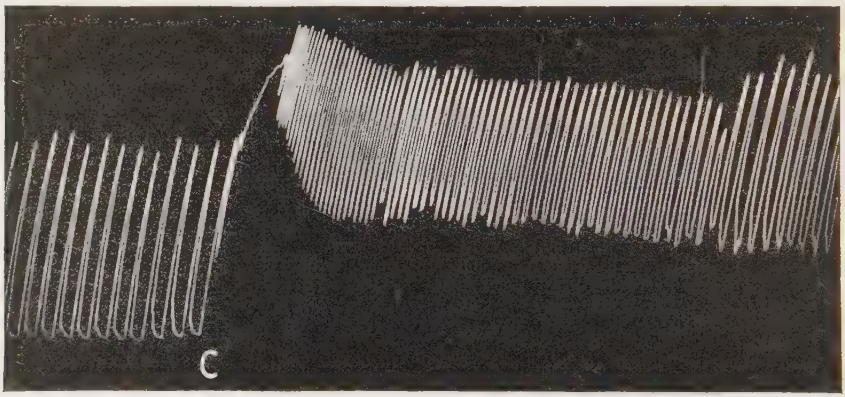
muscle contributes to it; for theobromine, which acts strongly on muscle while it has little effect on the central nervous system, fails to remove fatigue and to increase working capacity in the same degree as caffeine.

Circulation.—In man, ordinary doses of caffeine sometimes induce some slowing of the pulse, which apparently arises from a mild stimulation of the inhibitory centre in the medulla; but not infrequently no alteration in the pulse rate is observable. The blood-pressure does not appear to be materially altered by caffeine, a slight rise of 5–10 mm. occurring in individuals, but not very frequently. Sometimes palpitation is complained of in excessive tea and coffee drinkers, and this may perhaps indicate stronger action on the inhibitory centres, but may equally well be attributed to gastric disturbance. Taylor found the blood-pressure reduced by caffeine treatment in cardiac inefficiency, but this may perhaps arise indirectly from the diuresis reducing the blood volume.

When caffeine is injected in large quantities intravenously in animals, the heart is accelerated considerably without any significant change in the extent of systole and diastole. The acceleration is not dependent

on changes in the regulating nerves of the heart, but arises from a direct stimulating action on the cardiac muscle, and especially on that part from which the rhythm originates. Vagus stimulation has less effect than usual, but this is due to increased irritability of the heart and not to partial paralysis of the nerve ends. A similar acceleration is induced by caffeine after division of both accelerator and vagus nerves and after the paralysis of the inhibitory terminations by atropine. Still larger quantities of caffeine injected intravenously in mammals cause weakness and irregularity of the heart. The amounts used in therapeutics in man seem insufficient to induce either the acceleration or the subsequent irregularity observed in animals. The acceleration of the heart is not always accompanied by an increase in the amount expelled per minute (Bock), for the contractions may follow each other so quickly that there is not sufficient interval for the inflow of blood.

Fig. 20



Respiration of a rabbit which had been slowed by morphine. At *C*, caffeine was injected intravenously and the respiration was at once greatly accelerated and moved toward the inspiratory position.

The blood-pressure under these large intravenous injections in animals often rises to some extent, but not infrequently shows little alteration, and the increase in the blood-pressure is rarely significant. Caffeine tends to stimulate the vasomotor centre in the medulla, and this would raise the blood-pressure, were it not for a simultaneous widening of the vessels through a direct action on the walls; this neutralizes in large part the central action on the circulation, so that the blood-pressure shows only slight changes (Sollmann and Pilcher). When very large quantities weaken the heart, the blood-pressure falls to a considerable extent, but if convulsions supervene it may again rise.

When caffeine or theobromine is perfused through the surviving heart, the coronary arteries are dilated, and this has led to the use of these drugs in conditions in which narrowing of these vessels is supposed to be present. It has not been shown however that any dilation of the coronary vessels occurs from concentrations of caffeine that are possible in the human body.

In the frog's heart, caffeine in small quantities accelerates and strengthens the beat for a short time, while larger amounts slow the beat and lessen the relaxation of the heart, which finally passes into rigor resembling that seen in the skeletal muscles.

The **Respiration** is quickened by caffeine, owing to a stimulant action on the medullary centre. This is seen in the improvement of the respiration in cases of dangerous poisoning with alcohol, opium and other drugs which prove fatal by depressing the centre, but is much less marked in normal animals. The quicker respiration is often more shallow than before the administration of caffeine, but the total air breathed is increased and the blood is better aërated; the lessened content of carbon dioxide in the blood causes the breathing to be shallower through lessening the stimulus to the respiratory centre. The action of caffeine on the centre is thus diametrically opposed to that of morphine.

The **Temperature** has been found to be raised by caffeine through its action on the nervous centres and perhaps on the muscles. The increase is, however, comparatively insignificant (0.5–1° C.) and is seen only in cases in which an almost poisonous dose has been used.

The **Alimentary Tract** is not often affected by theobromine and caffeine, but after either of them discomfort and loss of appetite are sometimes complained of, probably owing to changes in the gastric mucous membrane. These are much more marked after even small doses of theophylline, and small hæmorrhages and erosions have been found in the stomach, both in man and animals (Allard).

Fig. 21

Caffeine diuresis in a rabbit. The amount of urine passed in ten minutes is represented by the height of the rectangles. The first of these, *A–B*, represent the normal secretion. At *B* a small dose, and at *C* a large dose of caffeine was injected intravenously, and the secretion is accordingly increased. The shaded part of the rectangles represents the amount of solids in the urine. It will be noted that these are increased but not in the same ratio as the fluid. The dotted line represents the average height of the blood-pressure during each period of ten minutes.

Kidney.—The most important property of caffeine from a therapeutic point of view is its power of increasing the secretion of urine. It is an everyday experience that strong coffee or tea increases the urine to a much greater extent than the same amount of water, and this has been shown to be due to the caffeine contained in these beverages. Caffeine injected intravenously in

the rabbit has a similar diuretic effect, though there is often a short preliminary period in which the secretion is actually diminished; this is especially marked when the injection is made rapidly, and may arise from circulatory changes or perhaps from the action of an overwhelming dose in the kidney itself.

It is often stated that the diuresis is due to dilation of the renal vessels, but more recent investigations have shown that there is no significant change in the vessels or in the flow of blood through the kidney. The increase in the urine must therefore be ascribed to some change in the blood, which allows the fluid to separate more easily from the colloids or to a change in the kidney cells. Each view has its adherents, but the simpler and more widely held one is that caffeine alters the permeability of the glomerular capsule and thus allows of a more rapid filtration through it. The rapid flow of this fluid through the tubule renders the reabsorption less complete, so that more of the glomerular filtrate reaches the ureter than usual.

Caffeine does not injure the kidney even when it is given in large doses and for prolonged periods; it thus differs from most other diuretics and may be administered in renal disorders without risk of increasing the lesions.

In the caffeine diuresis the fluid part of the urine is increased chiefly, but the solids also undergo an augmentation, though not to the same extent. Among the solids the chief increase is seen in the sodium chloride, the nitrogenous constituents undergoing less alteration, although they also rise in amount. The dilution of the urine reduces the concentration of acid, and in addition the alkali of the blood escapes through the kidney in larger quantity, so that the urine in caffeine diuresis is more nearly neutral and is less irritant to the urinary passages than normally.[1]

The excretion of large quantities of fluid in the urine is of course, accompanied by a diminution of the fluids of the blood, but the latter soon recuperates itself from the tissues. If there is any accumulation of liquid, such as œdema, it is drained into the blood to replace the fluid thrown out by the kidney, and caffeine may accordingly be used to remove œdema or dropsy in this way. If no such accumulation. exists, the blood draws on the fluids of the intestine and stomach, and their withdrawal leads to the sensation of thirst. As a diuretic, caffeine is distinctly inferior to theobromine; in the first place, because the diuresis is less certain and is often accompanied by nervous symptoms—sleeplessness and restlessness; and secondly, because the increase in the secretion is smaller and lasts for a shorter time. Theophylline is said to act on the kidney even more powerfully than theobromine.

Excretion.—Caffeine undergoes decomposition readily in the tissues, and the whole is destroyed or excreted within twenty-four hours. During

[1] A small amount of sugar is often found in the urine of rabbits after caffeine, and this has been stated to arise from an excess of sugar in the blood; this hyperglycæmia appears to proceed from excessive action of the suprarenal glands from the excitement in rabbits, and has no clinical significance (Stenstrom).

its passage through the body it loses its methyl groups and first becomes dimethyl- and then monomethylxanthine. Eventually xanthine is formed and this probably breaks up into urea. In the urine are found small quantities of the unchanged drug, accompanied by larger quantities of dimethylxanthine and monomethylxanthine. After theobromine and theophylline some of the unchanged drug is found in the urine along with monomethylxanthine. The uric acid of the urine is not increased by any of these drugs.

The exact order in which the methyl groups are lost in the tissues appears to differ in different animals; in the dog all three isomeric dimethylxanthines are formed from caffeine and after large doses appear in the urine, although theophylline predominates, while in the rabbit and in man paraxanthine is formed in larger amounts. The monomethylxanthines are also excreted in different proportions in different animals, heteroxanthine prevailing in man and the rabbit.

Tolerance.—A certain degree of tolerance is acquired from the prolonged use of coffee, tea, or chocolate, as is shown by the absence of diuresis. Apparently the caffeine and its allies undergo more rapid destruction, but this does not explain the tolerance completely; the tissues also cease to react to their presence after prolonged use.

Theobromine resembles caffeine in its effects except that it has little or no action on the central nervous system. It is esteemed a more powerful diuretic and generally has no other effects in man. When large doses are taken for some time, it tends to act on the stomach, causing loss of appetite and nausea.

Theophylline or **Theocine** is the most powerful diuretic of the group, but in a number of cases has had a deleterious action on the stomach and in several instances epileptiform convulsions have followed its use

Preparations.

Caffeina (U. S. P., B. P.), long, white, silky crystals, without odor, but possessing a bitter taste, soluble in 46 parts of cold water, more so in boiling water. 0.15 G. (2½ grs.); B. P., 1–5 grs. Caffeine is best prescribed either in powder or in tablets. It may also be given in water with salicylate of sodium, which aids its solution. The two following preparations are unsatisfactory:

Caffeina Citrata (U. S. P.), *Caffeinæ Citras* (B. P.), a white powder consisting of a weak chemical combination of citric acid and caffeine. It is decomposed by mixture with more than 3 parts of water. 0.3 G. (5 grs.); B. P., 2–10 grs.

Caffeina Citrata Effervescens (U. S. P.), *Caffeinæ Citras Effervescens* (B. P.), a mixture of citrated caffeine with sodium bicarbonate, tartaric and citric acids. On throwing the powder in water it effervesces, owing to the acids acting on the bicarbonate and liberating carbonic acid. This preparation contains only 2 per cent. of caffeine. Dose, 4 G. (60 grs.); B. P., 60–120 grs

Caffeinæ Sodio-benzoas (U. S. P.), a mixture of equal parts of caffeine and sodium benzoate, dissolves in about its own weight of water. Dose by mouth 0.3 G. (5 grs.), hypodermically 0.2 G. (3 grs.).

Theobromina (unofficial) is a crystalline powder even less soluble than caffeine, and is absorbed with difficulty when given alone.

Theobrominæ et Sodii Salicylas (B. P.), Theobrominæ Sodio-salicylas (U. S. P.), Diuretine, is a mixture of sodium-theobromine with salicylate of

sodium in approximately molecular proportions, and is soluble in one part of water. Dose, 1 G. (15 grs.) in powder form or in solution.

Theophyllina (U. S. P.) or theocine is a white crystalline powder, slightly soluble in water. Dose, 0.25 G. (4 grs.) in powder or tablets.

It is preferable in therapeutics to use the pure principles rather than such impure forms as Guarana (U. S. P.), or Kola nut.

Therapeutic Uses.—The action of caffeine on the central nervous system has led to its employment in a number of different conditions. Thus, in nervous exhaustion it may be used to stimulate the brain, and in collapse its action on the respiratory centres has been found of value. In narcotic poisoning with failing respiration, caffeine may be used to stimulate the centre in place of strychnine or atropine; in opium poisoning more particularly, strong coffee has long been used, but caffeine might be substituted with advantage. Its stimulant action on the brain, and more especially on the respiration, renders it an antidote in dangerous cases of alcoholic poisoning also. Some forms of migraine and headache are relieved by caffeine, but in others it seems rather to intensify the pain; this effect probably arises from the action on the brain and may be compared to the relief of fatigue; headache is often treated by a mixture of caffeine and one of the antipyretic series, such as phenacetine.

Caffeine has been used in diseases of the heart on the supposition that it increases the power of the heart like digitalis; but it has not any action on the heart in such quantities as can be used in therapeutics, and its use for this purpose is not founded on any accurate clinical observations. Its reputation as a cardiac stimulant may probably arise from its efficacy in removing dropsy in heart disease, but this is the result of its renal action and the heart is not affected directly. The view that these drugs can prevent spasm of the coronary vessels is far from being established either experimentally or clinically.

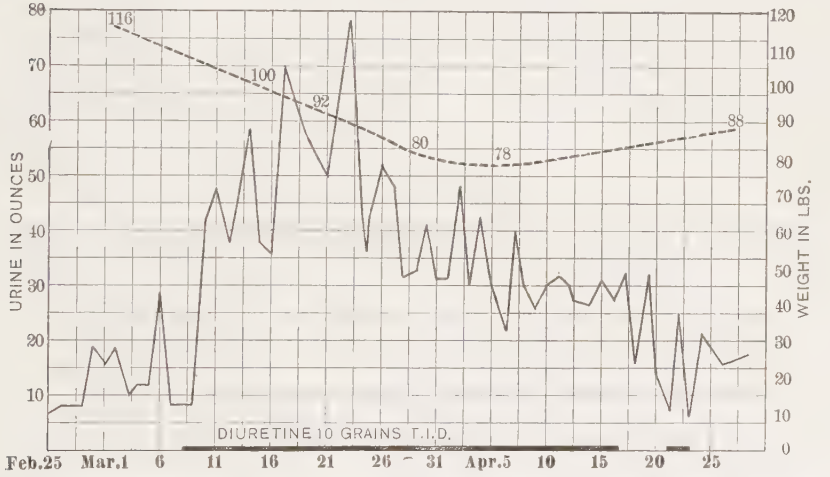
In their action on the kidney the members of the caffeine series stand preëminent, no other drug producing such a copious flow of urine as either caffeine or theobromine. As has been explained already, the latter is to be preferred to caffeine as a diuretic, and may be used in all cases in which there is a pathological accumulation of fluid in the body, whether of cardiac, hepatic, or renal origin. The results are most brilliant, however, in cases of cardiac dropsy, and here it may be prescribed along with one of the digitalis series. It must be emphasized, however, that in these cases it cannot supplant digitalis, but merely aids in the removal of the fluid. In cases of hepatic dropsy, caffeine and theobromine have also proved of service, although here the treatment can only be considered palliative. In renal dropsy theobromine has been used with somewhat variable results; it does not seem to increase the albumin in the urine, but not infrequently little or no diuresis follows its administration. This is only to be expected where the renal cells are in such a condition as to be incapable of responding. Where the disease is less developed, the members of this series produce the usual increase in the secretion. The question of the use

of these diuretics in renal disease is still undecided and requires further accurate observation. In experimental nephritis in animals they often act efficiently in washing out the detritus of the tubules, but it is unknown whether they have any permanent beneficial effect.

Inflammatory effusions do not seem to be lessened to any marked extent by either caffeine or theobromine.

Diuretics have often been recommended to promote the excretion of poisons and toxins from the tissues, and it is possible that they may be of value if the poison is in ordinary solution in the fluids of the body; when it is fixed by combination with the proteins or cells, as in mercuric poisoning or diphtheria, the diuresis is valueless. The saline diuretics have been used for this purpose more than caffeine or theobromine, in the hope that they would wash the poison out of the organs, as well as carry it through the kidney.

FIG. 22



Action of theobromine in cardiac dropsy. A case of cardiac dropsy treated with diuretine (theobromine-sodium salicylate) during the period marked with the black line below. Dose, 10 grs. three times a day. The urine per day in ounces is marked in the unbroken line. The body weight fell continuously (dotted line) as the dropsy disappeared, and when the normal weight of almost 80 pounds was reached, the diuresis became less marked, as there was no longer so much fluid to draw upon.

Other efficient diuretics are the saline diuretics (p. 300), and the mercurial salts. Digitalis and its allies also promote diuresis, but mainly indirectly by improving the circulation.

Coffee and Tea.

Coffee is not used in medicine, but is of great dietetic importance. The coffee bean contains about 1–2 per cent. caffeine, and a cup of coffee is equivalent to $1\frac{1}{2}$–3 grs. of caffeine along with some volatile substances, such as furfuralcohol, produced by the roasting; these have been called *Coffeon* and resemble in their action the volatile oils.

Tea contains a larger percentage of caffeine (about 1½–4 per cent.), but as less tea is used than coffee, each cup may be considered to contain 1½–3 grs. In green tea there is a considerable quantity of a volatile oil which also passes into the infusion, and the flavor of black tea also arises from volatile substances (*Theon*). Both black and green tea contain about 7 per cent. of tannic acid, but this is only extracted slowly. The bitter taste in tea that has been prepared too long is due to the tannic acid passing into solution.

The wakefulness and the relief from fatigue which are produced by tea and coffee are undoubtedly due to the caffeine contained in them. On the other hand, the feeling of well-being and comfort produced by coffee after a full meal is similar to the carminative effects of the volatile oils and appears to be due to the local action in the stomach of the volatile constituents of coffee. Apart from this local action, these volatile bodies seem to have no effect whatever on the economy. There is a widespread belief that excessive tea-drinking disturbes gastric digestion and this has generally been attributed to the tannic acid contained in it. It is not unlikely that the caffeine and theophylline may also play a part in this gastric action by causing irritation of the mucous membrane.

It was formerly stated that coffee lessened the tissue change and that it ought therefore to be included among foods, but it has been shown conclusively that far from lessening the metabolism of the body, coffee and tea increase it, the amount of urea and carbonic acid excreted being considerably augmented by their use. This is only to be expected from the increased activity of the nervous centres, which leads to increased movement and increased consumption.

Chocolate contains theobromine (0.5–1 per cent.), instead of caffeine, and besides this a large amount of fat (cacao-butter, 15–50 per cent.), starch and albumins. The theobromine does not possess the stimulant action of caffeine on the nervous system, and chocolate may therefore be taken where coffee or tea produces wakefulness. The starch and fat are assimilated by the tissues so that chocolate is a true food. But Neumann finds that cocoa retards the absorption of the proteins and fats of the food, especially those forms of cocoa in which the fat has been partially removed. On the other hand, cocoa with a large percentage of oil delays the gastric secretion and may give rise to a feeling of heaviness and discomfort in the stomach. Its continued use may cause dyspepsia, partly from this cause and partly from theobromine acting on the gastric mucous membrane. There is no question that the food value of cocoa and chocolate is often overestimated. It allays hunger, but this is only in part from its being a food, the local detrimental effect on the gastric mucous membrane tending to lessen appetite.

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Minor Diuretics.

A large number of vegetable drugs have enjoyed a reputation in the past as diuretics but are passing into disuse. Many of them owe their position merely to the large quantities of water in which they are taken; and some of them, such as barley, only lend body and taste to water. Others have a slight diuretic action in themselves but are superfluous since the introduction of caffeine and its allies.

Uva Ursi, the leaves of the bearberry, Arctostaphylos Uva Ursi, and of allied plants, contains two glucosides, *Arbutin* and *Methylarbutin,* along with large quantities of tannin and some inactive bodies. These glucosides are decomposed by the action of acids or of emulsin into glucose and hydroquinone or methylhydroquinone, and this change seems to occur in the body, for some hydroquinone appears in the urine though most of the arbutin is excreted unchanged; it is not unlikely that the decomposition occurs from bacterial action in the intestine.

Uva ursi is found to have some diuretic action, which is obviously due to its acting on the renal epithelium, and the urine is found to undergo putrefaction more slowly han usual. Both the diuretic and the antiseptic action appear to be due to the undecomposed arbutin, though the hydroquinone may reinforce the glucoside in retarding putrefaction.

The urine is often dark in color after uva ursi or arbutin, and this tint deepens when it is allowed to stand, from the hydroquinone undergoing further oxidation; a similar change occurs in carbolic acid poisoning. When decomposition of the urine occurs in the bladder, as in cystitis, the urine may have this dark color when passed.

Large quantities of uva ursi cause nausea, vomiting, and diarrhœa, but Lewin states that this disturbance of the alimentary canal may be avoided by administering the glucosides instead of the cruder preparations.

Buchu, the leaves of several species of Barosma, contains a volatile oil, which is excreted by the kidneys and increases the urine slightly; it also has a feeble antiseptic action in the urine.

Scoparius, the tops of the common broom plant (Cytisus scoparius), contains a resinous substance, *scoparin*, which seems to act on the kidney as a mild diuretic and accounts for the reputation which broom-tops have long enjoyed. The alkaloid sparteine, which also occurs in scoparius, has no action on the kidney.

Many other resinous bodies are used in popular medicine to increase the urine, but have little or no effect. Among these may be mentioned Zea, or cornsilk, and Chimaphila or pipsissewa. Cubebs, Copaiba, and Cantharides have some action as diuretics but are more useful for their other effects.

VIII. SALINE DIURETICS.

The amount of urine is increased by all solids which are eliminated by the kidney, as well as by an excess of fluid in the blood. For the kidney is unable to excrete solids except in solution, and every molecule which is passed through it carries with it a certain amount of water to augment the secretion. Only substances which can circulate in the body in considerable quantities can be used to increase the urine in this way, and in practice the chief diuretics of this class are comprised in the indifferent salts and similar harmless bodies. In order to act as diuretics these must be readily absorbed from the alimentary tract and this excludes a large class of salts which increase the urine greatly when they are injected intravenously, but which are absorbed with difficulty and are therefore used mainly for their effects on the intestine (see Saline Cathartics, p. 105).

Among the saline diuretics are the chlorides of sodium, potassium and ammonium, though these are seldom prescribed for this purpose; their diuretic action is seen, however, in the treatment at spas and watering-places. The cerebral action of the bromides precludes their use as diuretics, though an increased secretion of urine accompanies their use in therapeutics. The iodide of potassium is often added to other diuretics to reinforce their action, but is liable to induce other symptoms when given in large quantities. The typical saline diuretics are the nitrates of the alkalies and the urea group.

The **Nitrates** have a cool, saline taste, and ordinary doses taken in water have no effect except an augmented flow of urine. They have long been used as diuretics, more especially the nitrate of potassium. The diuresis is generally attributed to the salt-action, which increases the exchange of fluid between the blood and lymph and thus promotes the filtration in the kidney. The presence of nitrate and potassium ions in the filtrate retards the reabsorption of fluid in the tubules and thus leads to a larger proportion reaching the ureters.

Large quantities in concentrated solution may cause gastro-intestinal irritation, giving rise to pain in the stomach region, nausea, vomiting and sometimes diarrhœa, and blood may be present in the vomited matter and in the stools. The urine is often abundant, but may be scanty or entirely suppressed. In rare cases these symptoms were followed by

muscular weakness, apathy, collapse, and eventually coma and death. At the autopsy the stomach and intestines were found red and congested, and contained blood extravasations. The kidney is said to have presented the symptoms of acute nephritis and hæmorrhages in some cases of poisoning.

The effects of nitrates are for the most part those of an indifferent and diffusible salt, but it is possible that this may be reinforced by some further irritant action, for smaller quantities of the nitrates than of the chlorides are sufficient to induce irritation, and solutions of the nitrates isotonic with the blood cause irritation and congestion in the intestine and are slowly absorbed. This irritant effect of the nitrates has been explained by Binz and Barth as the result of the reduction of the nitrates to nitrites in the alimentary canal and tissues, but no symptoms of nitrite action seem to have been observed in cases of poisoning with nitrates. Haldane has shown that nitrite is formed from the nitrate used in the preservation of meat by salting, and that some nitrous-oxide hæmoglobin is formed and gives a bright red color to the meat. The presence of this pigment may perhaps explain the red color of the intestine in some cases of poisoning in which extravasations of blood are not marked.

The fate of the nitrates in the body is still obscure owing to difficulties in their quantitative estimation. Some of that ingested undergoes reduction in the alimentary tract and tissues, for the nitrite reactions are given by some organs and by the urine. And it seems likely that a portion may undergo still further reduction to ammonia or some of its compounds. Most of it appears in the urine as nitrate when large doses are given, but some investigators state that after moderate quantities in man (1–3 G.) they could observe no nitrate in the urine, the whole having undergone some change in the passage through the body. Some of the nitrate seems to be excreted in the saliva and perspiration, possibly unchanged, although it is rapidly reduced to nitrite in these secretions, and may in fact be changed to this form in the secretory cells.

Urea in the course of its excretion through the kidney carries with it a considerable amount of water, and when injected intravenously is a powerful diuretic. It is rapidly absorbed from the intestine and is practically devoid of action in the tissues even in large doses. Its diuretic action arises from its retaining water from being absorbed in the tubules, which are unable to take up much urea from the glomerular filtrate.

Ammonium Acetate and **Citrate** are indifferent salts but undergo oxidation in the tissues and finally form urea which acts as a diuretic in passing through the kidney. They were formerly supposed to increase the secretion of sweat but this action is insignificant.

Preparations.

Potassii Nitras (U. S. P., B. P.), Nitre, Saltpetre (KNO_3), 0.5 G. (8 grs.); B. P., 5–20 grs; colorless crystals with a cool, saline taste, very soluble in water, prescribed in dilute solution.

Urea ($CO(NH_2)_2$), colorless crystals with a cool saline taste, soluble in equal parts of water. Dose 1–4 G. (15–60 grs.), in solution.

Therapeutic Uses.—The saline diuretics are seldom used except as ingredients of diuretic mixtures; *e. g.*, along with digitalis, or to render the urine more dilute and thus to reduce its acidity in irritation of the genito-urinary tract. They were formerly employed largely in fevers and in various disorders of the metabolism, such as rheumatism or gout, but in none of these have they proved useful. The nitrates are to be given with care when there is any irritation of the stomach and intestine. Authorities differ as to whether these diuretics may be prescribed in irritation of the kidney, but in every case they ought to be well diluted.

Paper impregnated with saltpetre is used in asthma by burning it in the sick room, when the pyridine and nitrites relieve the spasms by relaxing the bronchial muscles. Saltpetre may be used in cigars or cigarettes for the same purpose, and the tobacco may contain also the leaves of belladonna or some of its allies, as these have a special action on the bronchial muscle.

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PERIPHERAL NERVOUS ACTION.

A considerable number of alkaloids act by interrupting the passage of impulses from the central nervous system to the peripheral muscles and organs in the same way as if the nerves were divided by operation, while others have the opposite effect of generating impulses in the periphery which arouse these peripheral organs with results which are identical with those following stimulation of the nerves supplying these organs. The point of action of these alkaloids has been definitely shown in all cases not to be the nerve fibres themselves but the apparatus in which they terminate. No poison is known that, circulating in the blood, affects the nerve fibres directly; all effects which at first sight appear to suggest this have been proved to arise from action at the origin of the neuron in the central nervous system, or at its termination in the periphery. Among these terminations, the peripheral ones of the afferent nerves (Fig. 23, *Ac*) seem peculiarly resistant to the action of drugs, for with the exception of aconitine and its allies, no drug is known to affect these when it reaches them by way of the circulation; on the other hand many drugs exercise a powerful action on them when applied to them directly, that is, in quantities which if carried in the blood would prove fatal from action elsewhere.

The efferent nerves are divided into two great classes which differ in many respects (Fig. 23). The first consists of those which, emerging from the central nervous system run direct to the voluntary muscles and terminate in expansions on the muscle fibres (Fig. 23, *III*). Certain drugs, of which curara is the type, interrupt the connection between these nerves and the muscles, so that stimulation of the nerve no longer causes contraction of the muscle, although direct stimulation of the muscle has its usual effect. Other alkaloids (*e. g.*, nicotine, physostigmine), which apparently act on the same point as curara but in the

FIG. 23

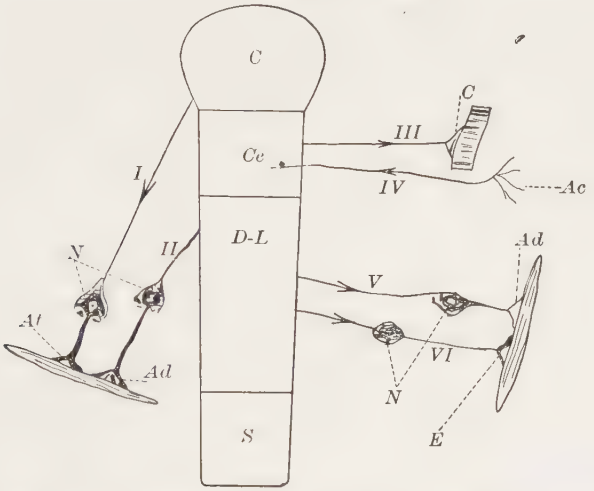

Diagram of the peripheral nervous system and its connections with the central axis; *I*, an autonomic nerve originating from the cranial division (*C*), and terminating in a ganglion *N*, from which a fibre runs to involuntary muscle; *II*, an autonomic sympathetic nerve rising in the dorso-lumbar cord (*D-L*) and passing to a ganglion from which a fibre runs to unstriated muscle; *III*, a nerve from the cervical cord running to striated muscle; *IV*, a sensory nerve from the skin to the cervical cord; *V*, an inhibitory, and *VI*, a motor sympathetic fibre running to ganglion cells from which fibres reach involuntary muscle. *N*, ganglia where nicotine acts; *At*, myoneural junctions of cranial autonomic nerve, where atropine acts; *C* indicates the point where curara acts; *Ac*, sensory ends (aconitine); *Ad*, sympathetic myoneural junctions (adrenaline); *E*, motor sympathetic endings (ergotoxine and adrenaline).

opposite direction, cause fibrillary twitching of the muscle fibres; but after curara, nicotine and physostigmine are ineffective unless in very large quantities and, on the other hand, the effects of a small amount of curara may be removed by those drugs.

The second group of efferent nerve fibres belongs to the autonomic system and end in a network around ganglion cells. From these ganglion cells, fibres proceed which again terminate in a network over a number of organs and muscles, which are not generally under the control of the will and are known as the vegetative organs. An impulse travelling from the central nervous system to such an organ as the heart thus

passes through two sets of terminations, those in the ganglia and those on the muscle or gland cell. There are thus two points at which drugs may interrupt the passage of impulses or at which they may originate new impulses. The network around ganglion cells is not known to be affected by any alkaloid, but the ganglion cell which is enclosed is the seat of action of a number of poisons, of which the type is nicotine. Stimulation of the ganglion cells, such as occurs under small quantities of nicotine, has the same result as electrical stimulation of the nerve fibres central to the ganglion (preganglionic) or between the ganglion and the peripheral organs (postganglionic); the same effect follows nicotine after the preganglionic fibres are divided, but no action is seen if the postganglionic fibres are divided or if their connections with the organs are paralyzed by other drugs. Paralysis of the ganglion cells, such as is caused by large doses of nicotine, has the effect of cutting off the impulses from the central nervous system, and electric stimulation of the preganglionic fibres is ineffective, while stimulation of the postganglionic fibres has its usual effect, and drugs acting on the terminations of these fibres are unchanged in action.[1]

All the autonomic ganglia react in the same way to nicotine, but it is otherwise with the connections of the postganglionic neurons with the organs, which are the only other points at which drugs can act on the path from the central nervous system to the periphery. Here it is found that certain alkaloids react with some terminations and not with others, and in some cases this has been correlated with their anatomical origin, in others with their physiological function. The autonomic system is divided into two great groups, the sympathetic, which originates in the thoracic and lumbar spinal cord, and the parasympathetic which rises from the cranial and sacral segments; the connections of the postganglionic fibres of these in the organs show marked divergences in their reaction to drugs. Thus adrenaline has the same effect as stimulating the whole of the sympathetic nerves (except the sweat nerves) and has no effect on the parasympathetic system; and it has been shown to exercise its action on the connections between the postganglionic fibres and the muscle. Ergotoxine similarly selects the sympathetic system, but only those of its fibres which transmit motor impulses, the inhibitory fibres remaining unaffected; and, again, the action is on the same neuromuscular connections of the postganglionic fibres. Stimulation by drugs of these neuromuscular connections has the same effect as stimulation of the nerve fibres; paralysis cuts off the impulses from the central nervous system, and also from the ganglia and postganglionic fibres. The parasympathetic fibres are selected by atropine and muscarine, though their action is not limited to these; many of the effects of atropine can be shown to be due to its inter-

[1] Anatomically the network round the ganglion cell corresponds to the nerve ends in voluntary muscle and the enclosed ganglion cell to the muscle fibre. It is, therefore, interesting to find that a number of drugs which act on the myoneural junction in muscle also affect the ganglion cells; examples are curara and its allies and nicotine. On the other hand some alkaloids which act on the myoneural junctions in voluntary muscle affect the myoneural junction of the postganglionic fibres (physostigmine).

rupting the nerve-muscle path of the parasympathetic system, while similarly muscarine stimulates the same points. On the other hand, some of their effects appear to arise from action at similar points on sympathetic postganglionic fibres. Not infrequently the motor innervation of an organ is derived from the parasympathetic division, while the inhibitory originates in the sympathetic or, *vice versa*, the cranial may be inhibitory and the sympathetic augmentor; in these instances the exact action of a drug may be difficult to determine owing to the fact that stimulation of the augmentor has the same effect as paralysis of the inhibitory terminations.

It was formerly taught that these drugs act on the terminations of the nerves which are recognizable histologically. But it has been shown in many instances that the action may be elicited in an organ whose nerves have been divided and have degenerated, and in which no nerve terminations survive. It is obvious, therefore, that the drugs do not produce their effects by action on the anatomical nerve end, but on something lying between it and the organ. This hypothetical point has been termed the myoneural junction and is supposed by Langley to contain specific receptors which combine with the poisons. The essential characteristic of the myoneural junction lies in the fact that it does not degenerate with the nerve and therefore is presumably of muscular origin, while on the other hand it is not contractile for it may be paralyzed (*e. g.*, by curara) without the contractility of the muscle being altered. It is convenient to continue the use of the words nerve ends or terminations in describing the action of these alkaloids, but these must be understood to connote not the anatomical structures but something intervening between them and the contractile substance.

IX. CURARA GROUP.

Curara, woorara, urari or woorali, is an arrow poison used by the natives of South America, who prepare it by extracting the bark of plants of the genus Strychnos, such as S. toxifera.

Different preparations of curara were found by Boehm to contain different alkaloids. That formerly obtainable owed its activity to *Curarine*, but the curara now exported contains *Tubocurarine*, which resembles curarine in its action, and *Curine*, a weaker poison, which has an entirely different effect. Another preparation examined by him contained three alkaloids, *Protocurine*, *Protocuridine* and *Protocurarine*, the last of which is the most powerful of all the curara alkaloids. Most of the experiments on which the statements regarding curara action are based, were performed with the crude drug, but the alkaloids seem to have a very similar effect, with the exception of curine.

Action.—The chief effect of curara is the arrest of all voluntary movements through an interruption of the connections between the peripheral nerves and the striated muscle fibres. In the mammal the muscles give way one after the other until the animal lies helpless on the ground. It can still move its limbs, but cannot recover its ordi-

nary position, and soon the limbs become totally paralyzed and the respiratory movements alone persist, although they too are slow, weak and jerky. Eventually the respiration ceases also, and asphyxia follows but is not betrayed by the usual convulsions owing to the motor impulses being unable to reach the muscles. The heart soon fails from the asphyxia and not through the direct action of the poison.

In the frog similar symptoms are seen, but here the arrest of the respiration is not necessarily fatal, as the skin carries on the exchange of gases, and recovery not infrequently occurs after two or even five days of complete paralysis. The cause of the curara paralysis was demonstrated by the classical researches of Claude Bernard and Kölliker. If the sciatic nerve of the frog be stimulated during the paralysis no movement follows, but if the artery of one leg be ligatured before the application of the poison this limb remains unparalyzed and reacts to reflex irritation, while the rest of the body is perfectly motionless. These facts can only be interpreted in one way; the paralysis is peripheral and not central, and may, therefore, be due to action either on the muscle, the nerve trunks, or the intermediate structures. That it is not due to the muscle is shown by the fact that direct stimulation causes the same movement as usual. On the other hand, in the experiment in which the artery is ligatured, stimulation of the nerves above the ligature, that is, where the poison has access to the nerve fibres, causes contraction, so that the nerve trunks do not seem affected. This may be shown in another way; if a nerve-muscle preparation be made and the nerve be laid in a solution of curara, contraction of the muscle still occurs on stimulation of the nerve, but if the muscle be laid in the curara solution stimulation of the nerve has no effect, while direct stimulation still causes contraction. Curara therefore acts on the connection between the nerve and muscle within the muscle itself and paralyzes it without previous stimulation.

Action on Nerve-ends.—Since the investigations of Bernard and Kölliker, the action of curara has been known to be peripheral, and it has been tacitly accepted that it could be localized in the anatomical structure known as the motor end-plates. Of late years facts have been accumulating which seemed difficult to reconcile with this view, and Langley has recently shaken its foundations by showing that curara continues to act after the muscle plate has lost its function. For the action of nicotine on the muscles is opposed by curara, not only in normal muscles, but also in those in which the nerves and nerve-endings have degenerated through section. The action of curara here must be exerted, not on the end-plate, but on some undegenerated substance, which has been termed the myoneural junction and which normally serves to transfer the nerve impulse from the nerve-plate to the actual contractile substance of the muscle.

Here, perhaps, better than elsewhere it can be shown that the condition of "paralysis" produced by poisons is analogous to that termed by physiologists "fatigue." It is known that on stimulating a nerve rapidly by electric shocks, or otherwise, the muscle at first contracts with every stimulation, but

eventually ceases to respond, owing to "fatigue" of the nerve ends, that is, to their inability to transmit impulses from the nerve to the muscle. If now the response to nerve stimulation of a muscle to which a minute quantity of curarine has been applied, be compared with that of a normal one, it is found that the poisoned one ceases to respond much sooner than the other—*i. e.*, its nerve ends become fatigued much sooner. The more curara is applied, the sooner does it fatigue, until at last no response at all can be elicited from it. The "paralysis" of the nerve terminations by curara then is of the same nature as physiological "fatigue," and other conditions of "paralysis" are also analogous to those produced by over-stimulation, though the exact condition of the paralyzed organ may not be the same as the fatigued one. Thus there is some reason to suppose that in the curarized terminations the substance which is normally consumed in transmission is present, but in a form which cannot be utilized, while in fatigue it has all been exhausted by the impulses which have already passed through.

Curara acts first on the nerves of the toes, ear and eye, later those supplying the limbs, head and neck, and, last of all, those supplying the muscles of respiration. At first slight movements can be performed, because single impulses can pass through the nerve ends, but sustained contractions such as are necessary to preserve the equilibrium, cannot be maintained, and the animal therefore falls. The intermittent impulses to the respiratory muscles still allow time in the interval for the recovery of the terminations, but as the intoxication proceeds the number of impulses which can pass through becomes fewer and fewer, and the movement therefore assumes more and more the character of a jerk and eventually ceases.

Small doses do not affect the innervation of unstriped muscle, and the strict demarcation of its action is seen very distinctly in organs which consist partly of striated and partly of unstriated fibres. Thus in the œsophagus, the striated muscle fibres no longer contract on stimulation of the vagus after curara, while the unstriated continue to respond as usual. In the iris of the mammals, which consists of unstriated muscle, curara has no effect, while the striated muscle of the bird's iris ceases to respond to stimulation of the motor oculi, but contracts on direct stimulation. The terminations of the nerves in the heart are not affected, but the nerves of the lymph hearts of the frog are paralyzed. The nerve ends in striated muscle in invertebrates appear to be immune to curara (Straub). The nerve fibres seem unaffected by curara, for stimulation causes the usual electrical changes in them.

The Sympathetic Ganglia are paralyzed by large doses, and stimulation of the preganglionic nerve fibre has no effect. For example, stimulation of the vagus does not slow the heart, and stimulation of the chorda tympani does not cause secretion because the impulses fail to pass the ganglia on their course. The terminations of the postganglionic fibres are not affected apparently, for stimulation beyond the ganglia has its usual effect.

The peripheral terminations of the afferent or sensory nerves seem unaffected, for if the artery of one leg be ligatured before the application of curara, reflex movements may be obtained in it from stimulation of

any part of the body, while if the sensory terminations were paralyzed, reflexes could be elicited only by the irritation of parts to which the poison had not penetrated, *i. e.*, from the ligatured leg.

The central nervous system is stimulated by large quantities of curara, and when it is applied directly to the brain and cord without reaching the muscles, it causes violent spasms (McGuigan), which appear to resemble those of the picrotoxin series rather than those induced by strychnine. The heart is not directly affected, but large quantities may paralyze the vagus ganglia and release the heart from inhibition. At the same time the blood-pressure may fall from paralysis of the ganglia on the vasoconstrictor nerves. The movements of the intestine, spleen and other organs are sometimes accelerated through a similar paralysis of the ganglia on inhibitory nerves.

Metabolism.—The cessation of the ordinary movements after curara and under artificial respiration naturally reduces the metabolism, but if the temperature is kept up by the external application of heat, the tissue change is not arrested in the muscles, and the CO_2 excretion and O_2 absorption are only slightly lower than those of the unpoisoned animal at rest. Sugar and lactic acid are often found in the urine after curara, but this is due to partial asphyxia and not to the direct action of the poison; the glycogen of the liver and muscles disappears from the same cause.

Curara is **excreted** by the kidneys apparently unchanged. It has long been known that this arrow poison may be swallowed with impunity, provided there is no wounded surface in the mouth or throat, and that it is therefore perfectly safe to suck the poison from a wound. This has been explained in various ways, some holding that the absorption from the stomach is so slow that the kidneys are able to excrete the poison as fast as it reaches the blood and that this prevents its accumulating in sufficient quantity to affect the tissues. Others suppose that the liver retains and destroys it, and a third view is that it is rendered innocuous in passing through the stomach walls.

The characteristic action of curara on the myoneural junction in striated muscle is antagonized to some extent by physostigmine, nicotine, and some other alkaloids.

Curine, the second alkaloid found by Boehm in some specimens of curara, is a much less poisonous body than curarine. It possesses some action on the heart, the same appearances following its injection in the frog as after digitalin and veratrine, while in mammals the rhythm is slow even after paralysis of the inhibitory mechanism.

Curara is an extract of varying constitution and strength and the active constituents are freely soluble in acidulated water, Attempts have been made to use curara in various forms of convulsive spasms, but without adequate results.

Paralysis of the terminations of the motor nerves in striated muscle—the so-called "Curara-Action"—is elicited by a large number of poisons, but in few of them is it the first effect of their application. Many drugs induce it only when injected in large quantities and at the end of a series of phenomena produced by their action on other parts of the body; it is observed much more frequently in frogs than in mammals, and is often of little importance compared to the other symptoms. Among the bodies which resemble curara more

closely in their action, the peripheral paralysis playing the chief rôle in their effects, are the ammonium compounds formed from the natural alkaloids by the substitution of an alkyl, *e. g.*, methylstrychnine, amylquinine, etc.[1] Some of the ammonium salts and many of the alkyl combinations of ammonium, phosphorus, arsenic and of several metals, also cause it. Of greater practical importance is the fact that the venom of the Cobra and of other colubrine snakes has the same point of action as curara, from which it differs in the slowness of its action and the tenacity with which it holds the nerve ends.

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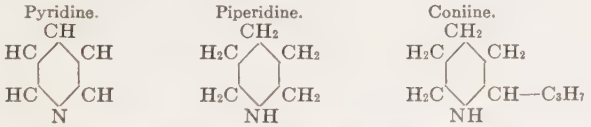
Coniine.

Coniine is one of the simpler derivatives of *Piperidine*, which is obtained from *Pyridine* by reduction. A series of alkaloids may be formed from piperidine by substituting methyl, ethyl, propyl or other alkyls for hydrogen, and one of these, propyl-piperidine, is the natural alkaloid coniine and was the first alkaloid to be formed synthetically.



Coniine is found in Hemlock (Conium maculatum), along with two nearly allied alkaloids, *Methylconiine* and *Conhydrine*. The action of these and of the other simple piperidine compounds resembles that of coniine, but is much weaker.

Symptoms.—The general symptoms induced in man by poisonous doses of coniine are weakness, languor and drowsiness which does not pass into actual sleep. The movements are weak and unsteady, the gait is staggering, and nausea and vomiting generally set in, along with profuse salivation. In most cases the intelligence remains clear to the end, as is related of the death of Socrates from hemlock poisoning, but in some instances imperfect vision and hearing have been noted. The pupils are somewhat dilated. Tremors and fibrillary contractions of the muscles are often seen in animals, and some observers state that actual convulsions occur. The breathing becomes weaker and slower and death occurs from its arrest.

Action.—Coniine does not possess any action of importance on the central nervous system. It is possible that in fatal poisoning the respiratory centre may be depressed, but most observers believe that the terminal asphyxia is due to paralysis of the nerve terminations in the respiratory muscles. And the twitching and tremor which are sometimes seen, appear to arise from a partial paralysis

[1] Boehm has stated that tubocurarine, which is the active constituent of much of the modern curara, is really one of those methyl bases (methylcurine).

of the peripheral nerves similar to that seen under curara. It also resembles curara in paralyzing the sympathetic ganglia, but this paralysis seems to be preceded by a short stage of stimulation; the ganglia are affected by quantities of coniine which are insufficient to cause paralysis of the nerves to voluntary muscle, but its action on these ganglia is not so powerful as that of nicotine, and the details of this action may therefore be left for discussion under the latter drug.

The heart is affected through the stimulation and subsequent paralysis of the ganglia on the inhibitory fibres, which lead first to slowing and later to some acceleration of the pulse. The blood-pressure is increased for a short time from stimulation of the ganglia on the course of the vasoconstrictor nerves. The respiration is sometimes accelerated slightly at first but soon becomes slow and labored, and then irregular, and finally ceases while the heart is still strong. The red blood cells of the frog show numerous vacuoles in coniine poisoning and these persist long after recovery (Gürber).

Coniine is rapidly **excreted** in the urine, so that its action passes off very soon even when quite large doses are taken. The treatment of coniine poisoning therefore consists in evacuation of the stomach and artificial respiration.

Piperidine acts in the same way as coniine, but more weakly, while methyl- and ethyl-piperidine stand between them in toxicity.

Pyridine resembles piperidine in most features but does not paralyze the ganglia nor increase the blood-pressure. It is excreted in the urine as methyl-pyridine, a combination between it and the alkyl occurring in the tissues. A similar synthesis occurs between methyl and tellurium (see Tellurium).

Quinoline and isoquinoline cause in mammals a condition of collapse similar to that seen under the antipyretics and the benzol compounds.

Hemlock or **Conium**, long widely used in therapeutics, has failed to maintain its position on more accurate investigation and has passed into disuse.

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Gelsemium.

Gelsemium sempervirens (Yellow Jasmine or Carolina Jasmine) contains several alkaloids, of which *Gelsemine*[1] is inactive in mammals, while a mixture of two or more alkaloids, which is known as *Gelseminine*, is a poison of the coniine type and is the real active principle of the drug as far as mammals are concerned.

Action.—The symptoms of gelsemium poisoning resemble those of coniine so closely that the reader may be referred to the description given under the latter. There is here again a question whether the final asphyxia is due to paralysis of the respiratory centre or of the nerve terminations, but most investigators lean to the view that the action is central and arises from a gradual depression of the medullary centre.

The pupil is very widely dilated by gelseminine when a solution is applied locally to the eye, much less so in general poisoning, in which the respiration generally fails before the pupil is fully dilated. The power of accommodation

[1] Gelsemine is frequently known as gelseminine, a use of the term which leads to some confusion, and which is not based on the history of the drug.

is also entirely lost when gelseminine or gelsemium tincture is applied to the eye. This mydriatic effect has not been explained, but the most plausible suggestion would seem to be that gelseminine paralyzes the terminations of the oculomotor nerve in the eye in the same way as atropine. Gelseminine differs from atropine in its behavior to other nerves, however, for it paralyzes the inhibitory cardiac fibres and the chorda tympani through acting on the ganglionic structures on their course and not on the extreme terminations. Its action on the ganglia, as far as it is known, resembles that of coniine, but it does not cause any increase in the arterial tension, such as is observed under this poison.

The tincture of gelsemium (U. S. P., B. P.), has been employed in doses of 4 mins. in facial neuralgia, and a mixture of the alkaloids has been applied locally to dilate the pupil, but has never attained any wide use.

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Sparteine.

Another alkaloid which resembles coniine closely in its action is *Sparteine*, which is found in the common broom plant (Spartium or Cytisus scoparius), and in various species of lupines. It is a pyridine derivative possessing the formula $C_{15}H_{26}N_2$, and is a fluid, but forms crystalline salts.

Action.—The general effects of sparteine are almost identical with those of coniine, but it seems very probable that the central nervous system is little affected by it, the whole of the phenomena pointing to a paralysis of the motor nerve terminations and of the sympathetic ganglia. Sparteine has more effect than coniine on the heart, which it depresses, so that the rhythm is slow and the contractions weak. When injected into a vein, sparteine induces less increase in the arterial tension than coniine, probably because the contraction of the vessels is counterbalanced by the weakness of the heart. No increase in the arterial tension is observed from the administration of sparteine internally and even the slight rise of pressure induced by intravenous injection is of only short duration.

Sparteine is much less poisonous than either coniine or gelseminine: it proves fatal to animals by paralyzing the terminations of the phrenic nerves in the diaphragm.

The slow pulse and slight rise of pressure observed in experiments in animals when sparteine is injected intravenously have led some writers to ascribe to it an action similar to that of digitalis, and at one time sparteine was used to some extent as a substitute for the latter; both experimental and clinical observations, however, go to show that these claims are quite unfounded, and sparteine is comparatively little used at the present time.

Sparteine sulphate (U. S. P.), has been advised in heart disease in doses varying from $\frac{1}{4}$ gr. up to 12 grs. Its reputation appears to have arisen from the use of broom tops as a diuretic, but this action is not due to the sparteine, but to scoparin (p. 300).

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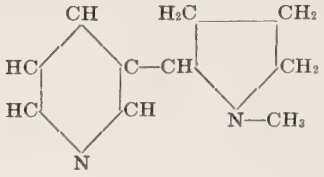
X. NICOTINE GROUP.

Nicotine, the well-known alkaloid of tobacco (Nicotiana tabacum), is a volatile fluid, possessing a strong alkaline reaction, and forming salts with acids, most of which are amorphous. It is a combination of pyridine with a hydrated pyrrol ring as shown by the structural formula—



Nicotine is the only constituent of tobacco which possesses any toxicological interest, although several other alkaloids are present in comparatively small amounts. It is accompanied by a volatile oil in dried tobacco, but this is only developed during the processes of preparation and seems to have no action apart from that of the other volatile oils. The odor and flavor, and probably the "strength," of tobacco depend in part upon the quantity and quality of this oil, in part on some products of the decomposition of nicotine. Absolutely pure nicotine has comparatively little odor, but it decomposes when kept, becomes dark colored, and acquires the characteristic odor of tobacco.

Nicotine is also found in the pituri plant (Duboisia Hopwoodii), the leaves of which are used by the Australian natives in the same way as tobacco by the civilized races.

Lobeline, an alkaloid or mixture of alkaloids obtained from Lobelia inflata or Indian Tobacco, and *Cytisine*, ($C_{11}H_{14}N_2O$), the alkaloid of laburnum (Cytisus laburnum), gorse and other plants, resemble nicotine very closely in action, and another body of the same type of action is the artificial quaternary ammonium base, *Methylhordenine*.

These alkaloids act chiefly on the central nervous system, the sympathetic ganglia, and the myoneural junctions in voluntary muscle.

Symptoms.—Poisonous doses administered to man or other mammals cause a hot, burning sensation in the mouth, which spreads down the œsophagus to the stomach, and is followed by salivation, nausea, vomiting, and sometimes purging. The breathing is quick, deep and labored, and is often accompanied by moist râles. The pulse is generally slow and sometimes weak at first, and then becomes very rapid, but after very large doses may be first accelerated and then slow and feeble. Some mental confusion, great muscular weakness, giddiness and restlessness are followed by loss of coördinating power and partial or complete unconsciousness. Clonic convulsions set in later, accompanied by fibrillary twitching of various muscles, and eventually a tetanic spasm closes the scene by arresting the respiration. In other instances the convulsions are followed by collapse with complete relaxation of the muscles, the reflexes disappear, the respiration becomes slow and

weak and finally ceases, the heart continuing to beat for some time afterwards. Very large doses of nicotine may prove fatal within a few seconds; the symptoms are those of sudden paralysis of the central nervous system, including the respiratory centre, and no convulsions are developed. Nicotine is about as poisonous as prussic acid.

In the frog the same excitement and violent convulsions are seen as in mammals, but the respiration soon ceases, and there follows a "cataleptic" stage in which the animal assumes a characteristic attitude. The fore legs are crossed in front of the sternum and are rigid, the thighs are at right angles to the axis of the body and the legs are flexed on them but are not rigid. When a leg is drawn down it at once returns to its original position, and the frog still attempts to escape when it is aroused. Fibrillary contractions are observed in many of the muscles. Somewhat later, the reflexes disappear, the muscles become flaccid, and eventually complete paralysis occurs from a peripheral, curara-like action.

Nicotine has but little toxic action on the lowest invertebrates, but as the nervous system begins to be differentiated it causes paralysis, and still higher in the scale the paralytic action is preceded by a stage of stimulation.

Circulation.—The action on the circulation is extremely complex, as a number of factors are involved. After moderate quantities the heart is slow and may stand still in diastole for a few seconds, but then recovers gradually and regains its former rhythm or becomes somewhat quicker. The slow pulse is due to stimulation of the ganglia on the vagus nerve (Fig. 24, *N*), exactly the same effects being produced as by stimulation of the vagus fibres in the neck. It is not affected by section of the cervical pneumogastric, as the path from the ganglia to the cardiac muscle fibres is still intact, but on the other hand, it is prevented by atropine, which paralyzes the terminations of the postganglionic fibres, and therefore blocks the passages of impulses from the ganglia to the muscle. It is also prevented by a number of drugs, such as curara and coniine, which paralyze the ganglia.

This stimulation of the ganglia is of short duration, soon passing into paralysis, so that on stimulating the vagus after nicotine there is no slowing of the heart but often some acceleration, due to the fact that the accelerating fibres running along with the inhibitory in the vagus nerve have no ganglionic apparatus in the heart, and are therefore unaffected by nicotine. Although inhibitory impulses can no longer reach the heart from above, stimulation of the venous sinus in the frog still causes arrest of the heart, since the stimulating current here reaches the inhibitory nerves beyond the paralyzed ganglia (Fig. 24, *X*), and these preserve their usual irritability. In the same way muscarine, which acts upon the postganglionic inhibitory terminations in the heart muscle (Fig. 24, *M*), can slow the rhythm even after the ganglia have been paralyzed by nicotine.

In addition to its action on the peripheral inhibitory ganglia, nicotine seems to stimulate the vagus centre in the medulla, as the slowing

is greater when the vagi are intact than when they are divided. But apart from this action on the inhibitory apparatus, nicotine also stimulates, and in large quantities paralyzes, the ganglia on the accelerator fibres, so that when the inhibitory mechanism has been put out of action by atropine, moderate quantities of nicotine increase the rate,

Fig. 24

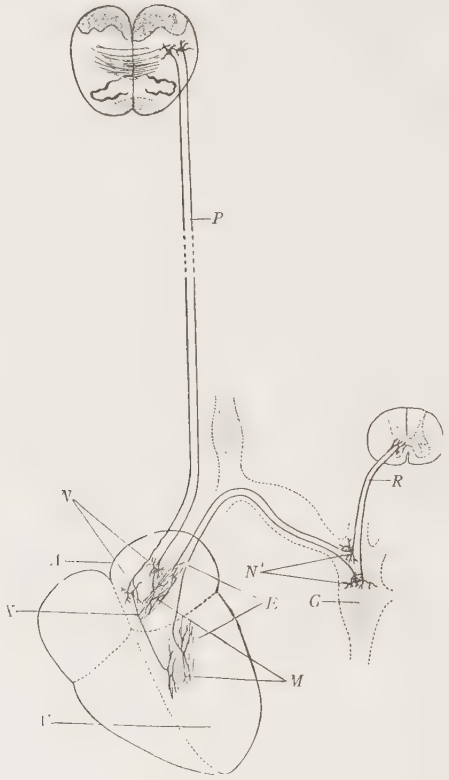


Diagram of the regulating nerves of the heart. *P*, inhibitory parasympathetic fibres vragus), terminating around ganglion cells in the auricle (*A*). The axis cylinders issuing fom these cells terminate on the muscular fibres of the auricle and ventricle (*V*). *R*, accelerator sympathetic fibres terminating around ganglion cells in the stellate ganglion *G*. The axis fibres of these ganglion cells run through the *Annulus Vieussenii* and terminate on the muscular fibres of the auricle and ventricle. *N*, *N'* points at which *nicotine*, *coniine*, *curarine*, etc., act—the ganglion cells surrounded by the terminations of the nerves, *M*, points at which *muscarine* and *atropine* act—the terminations of the postganglionic fibres which arise from the intra-cardiac ganglia on the parasympathetic path. *E*, points at which *adrenaline* acts—the myoneural junction on the sympathetic path.

while larger amounts paralyze the accelerator ganglia (N', Fig. 24) and thus tend to slow the heart. A further action is said to be exercised on the heart muscle itself, which is first stimulated and then depressed (Wertheimer).

On the injection of nicotine into a vein or subcutaneously, an im-

mense augmentation of the arterial tension occurs; this is due in part to stimulation of the vasoconstrictor centre in the medulla, in part to stimulation of the ganglia on the course of the vasoconstrictor nerves.

The constriction of the vessels can be observed in many parts of the body —mesentery, foot, rabbit's ear, etc. In these parts the pallor produced by the narrowing of the vessels is followed by redness and congestion owing to the paralysis of the ganglia, and at the same time the pressure falls to a level somewhat below the normal. In some parts of the body no constriction of the vessels occurs; for example, the dog's lip and mouth are congested first and then become pale. This flushing seems partly due to the stimulation of the ganglionic apparatus on the vaso-dilator fibres for the lips and mouth, and partly to the constriction of the vessels in the splanchnic area diverting the blood current to those parts which are less abundantly supplied with constrictor fibres, for it occurs after removal of the superior cervical ganglion containing the vasodilator fibres.

After a few minutes the blood-pressure falls to the normal level or lower, but a second injection again produces a similar rise in the arterial tension, unless the first was large enough to weaken the ganglia.

In the rabbit nicotine tends to induce lesions of the aorta with subsequent calcareous degeneration, which resembles the atheromatous patches seen in man. This is due to the very high blood-pressure, and similar effects are seen from adrenaline and from other measures which increase the blood-pressure, such as pressure on the abdominal aorta.

Respiration.—The respiration is at first rapid and shallow with some deficiency in the expiratory movements, but after a time, while maintaining the acceleration, it becomes deeper. It is liable to be interrupted at this stage by the convulsions, but if these do not prove fatal, it gradually becomes slower while remaining deep. Later, pauses in the position of expiration appear, and the movements become weaker until they disappear, the animal dying of asphyxia. The respiratory centre is first stimulated and then depressed and paralyzed and its failure is the cause of death, the heart continuing to beat for some time afterwards although slowly and weakly.

The bronchial muscle relaxes after a transient constriction when nicotine or lobeline is ingested, these changes being brought about by stimulation of the ganglia on the course of the vagus fibres which cause contraction of the bronchial muscle, and later of those on the sympathetic fibres which inhibit the contraction.

Most of the **Secretions** are increased temporarily by nicotine. The glands investigated have generally been the salivary, where it is found that the secretion is increased by the injection of small quantities, but is afterward depressed, while large doses diminish it at once. The seat of action is again the ganglionic apparatus on the secretory nerves. If the chorda tympani is stimulated in the normal animal a large secretion of saliva at once follows, but if a sufficient quantity of nicotine be injected, no such effect follows its stimulation. If, however, the nerve fibres are stimulated between the ganglion cells and the gland (at *X* in Fig. 25), the secretion again follows as before. On the other

hand, nicotine increases the secretion whether the chorda is intact or not, but ceases to act if the connection between the ganglion cells and the gland is interrupted. Nicotine thus first stimulates and then paralyzes the ganglia on the course of the chorda tympani and of the sympathetic fibres supplying the gland. Pilocarpine and muscarine cause profuse salivation after nicotine because they stimulate the

FIG. 25

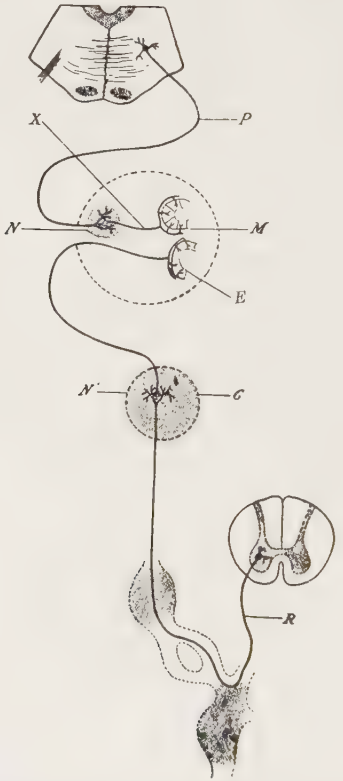


Diagram of the innervation of the submaxillary gland. *P*, parasympathetic fibres (chorda tympani), terminating around a ganglion cell in the hilus of the submaxillary gland. The axis from this ganglion cell runs to the secretory epithelium. *R*, sympathetic fibres, terminating around a ganglion cell in the superior cervical ganglion *G*. The axis from this cell runs to the secretory epithelium. In the diagram the nerves are represented as running to separate acini. *N*, *N'*, ganglion cells surrounded by the terminations of the nerves—the points at which *nicotine* acts. *M*, the terminations of the secretory fibres connected with the chorda tympani—the points at which *atropine*, *muscarine*, and *pilocarpine* act. *E*, the terminations of the secretory fibres connected with the sympathetic —the point at which *adrenaline* acts.

postganglionic terminations in the gland cells, and it is therefore immaterial whether the connection with the central nervous system be interrupted or not. On the other hand, the reflex secretion of saliva normally produced by irritation of the mouth or by chewing is prevented by nicotine. Atropine stops the secretion produced by nicotine by paralyzing the postganglionic terminations.

The other secretory glands are affected in the same way by nicotine, their secretions being first increased by the stimulation of the ganglia on the course of their secretory nerves, and then being lessened by their paralysis. Thus the secretion of sweat and bronchial mucus is found to be markedly increased. The urine and bile have not been shown to be affected by nicotine, as their secretion does not seem to be so dependent upon nervous influences. The activity of the suprarenal glands is increased by nicotine, probably by its action on the ganglia on the course of the innervating fibres; this results in an augmented secretion of adrenaline into the bloodvessels, which in turn affects a number of organs, such as the iris and uterus, and introduces a new complication in the action of nicotine.

Nicotine produces extreme **Nausea and Vomiting** when taken even in comparatively small quantities, a fact which is generally recognized by tyros in smoking. This is in part central in origin, in part due to the powerful contractions of the stomach walls. This contraction extends throughout the intestinal tract, so that repeated **Evacuation of the Bowel** occurs. Somewhat larger quantities may lead to a tetanic contraction of the whole intestine with almost complete obliteration of the lumen. This exaggeration of the peristaltic contraction is probably due to stimulation of the motor ganglia in the intestinal wall, and a subsequent paralysis of these structures leads to a failure of local stimuli to induce peristalsis. A further effect of nicotine in the bowel is due to its stimulating the ganglia on the fibres of the splanchnic which inhibit the rhythmical pendulum movements. These are arrested by the injection of nicotine, but return in exaggerated form as the ganglionic stimulation passes into paralysis. The mesenteric vessels are narrowed at first from stimulation of the ganglia on the course of the vaso-constrictor nerves, but congestion follows the depression of these ganglia and the blood-pressure falls.

Similar changes are produced by nicotine in the bladder, which is thrown into tetanic contraction. The urine is therefore expelled very soon after the injection of nicotine and this probably gave rise to the erroneous view that the renal secretion was increased. The uterus is strongly contracted in pregnant animals, but is inhibited in the non-pregnant cat, in which the inhibitory nerves are more powerful than the contractor ones.

The action of nicotine on the **Pupil** varies in different animals, for while in the cat and dog its application either intravenously or locally produces marked but transitory dilation, in the rabbit partial constriction sets in immediately. In cases of acute poisoning in man contraction is generally seen at first and is followed by dilatation. In birds nicotine causes very marked contraction of the pupil, apparently owing to direct action on the muscle of the iris. The size of the pupil is regulated by two sets of nerves, the motor oculi and the sympathetic, and the ciliary fibres of both of these are interrupted by ganglia in their passage from the brain to the iris, those of the motor oculi by the ciliary ganglion, those of the sympathetic by the superior

cervical ganglion (see Fig. 26, p. 327); the varying effects of nicotine may be due to its stimulating the one ganglion more strongly in one species of animals, the other in another. It is found, however, that atropine does not remove the effects of nicotine on the rabbit's eye, which would seem to indicate an action on the muscular fibres of the iris. Several other effects on the orbital muscles are seen; thus in cats and dogs the nictitating membrane is withdrawn, the eye opens and is directed forward, while in the rabbit these symptoms are preceded by a stage in which the nictitating membrane is spread over the cornea and the eye is tightly closed; these all arise from stimulation and subsequent paralysis of the superior cervical ganglion.

Nicotine, then, first stimulates and later paralyzes all the **Autonomic Ganglia**, whether applied locally to them or injected into the circulation. In these ganglia, the characteristic formation is the basket-like arrangement of the terminations of the entering nerve, which surround a large nerve cell from which an axis cylinder runs to the muscle or secretory cell. A nerve impulse from the central nervous system passes from the basket to the cell and thence to the periphery. Langley has shown that nicotine acts on the cell of the peripheral neuron, and not on the network around it, for the same effect is obtained from the application of the poison after the network has degenerated.

In the frog nicotine produces fibrillary twitching and slow, prolonged contraction of the **Muscles**, which are not prevented by previous division of the nerves leading to them, but disappear on the injection of curara; on the other hand, the paralysis induced by curara may be partially removed by small quantities of nicotine. This indicates that the fibrillary contractions arise neither from action on the central nervous system nor on the contractile substance of the muscle itself. And Langley has recently shown that the fibrillary twitching and slower contractions occur in muscles in which the nerve ends have degenerated from division of the nerves, so that nicotine acts on some receptive substance peripheral to the anatomical nerve ends and intervening between these and the contractile substance of muscle. A similar effect is seen in reptiles and birds; in mammals the twitching of the muscles is prevented by section of the nerves, and is, therefore, due to central action, but large quantities of nicotine cause paralysis exactly like curara.

The convulsions seen in both cold- and warm-blooded animals evidence the influence of nicotine on the **Central Nervous System**. The spinal cord is thrown into a condition of exaggerated irritability, and the reflexes are correspondingly increased, but the convulsions do not seem to be due so much to the spinal cord as to the medulla oblongata and hind brain, for they are not tonic but clonic in character, and are much weaker after division of the cord immediately below the medulla than in the intact animal. The medullary stimulation also betrays itself in the rapid and deep respiration, and is in part responsible for the inhibitory slowing of the heart and the rise in the blood-pressure. The higher centres in the brain seem to participate but

little in the stimulant action of nicotine, which is short-lived, and soon gives way to marked depression of the whole central nervous system, manifested in the slow respiration, the low blood-pressure, the disappearance of the reflex movements and the final unconsciousness.

The **Excretion** of nicotine is probably carried on mainly by the kidneys, for it is found in the urine very soon after it enters the blood. It has also been detected in the saliva and perspiration. It has been shown repeatedly that nicotine and some other alkaloids are weakened in toxic effect or rendered entirely inactive by being mixed with an extract of the liver or of the suprarenal capsules; but no satisfactory explanation is forthcoming, though there is every reason to suppose that much of the nicotine absorbed from the stomach and intestine is thus modified in its passage through the liver.

When small quantities of nicotine are ingested repeatedly, the body soon gains a certain **Tolerance**, and no symptoms whatever are produced by doses which in ordinary cases would produce grave poisoning. A familiar example of this tolerance is seen in the practice of smoking. The first use of tobacco in the great majority of individuals is followed by vomiting and depression, which may even amount to collapse, but after a few experiences no symptoms follow smoking, owing to the cells of the body becoming tolerant of the poison and learning to destroy it more rapidly (Dixon and Lee). In some individuals no such tolerance is developed, and in every case the tolerance is much more limited and more difficult to acquire than that for morphine. In animal experiments it is often found that while one application of nicotine produces considerable ganglionic stimulation, the second has much less effect. This is probably due, not to the establishment of tolerance, but to the first dose having produced primary stimulation and then depression of the ganglia, this depression, while not amounting to complete paralysis, being sufficient to counteract to some exent the stimulant action of the second injection. True tolerance is attained very imperfectly by animals from the use of repeated small doses, but when larger amounts are used some tolerance is soon acquired (Edmunds). Animals which have acquired tolerance for nicotine also resist the action of lobeline.

Therapeutic Uses.—Lobelia was formerly used as an emetic, but is unreliable, and is liable to give rise to the most alarming symptoms of poisoning. It is occasionally used in the form of the tincture (Dose, U. S. P., 1 mil; B. P., 5–15 mins.), to relax the spasm of the bronchial muscle in asthma, and may also aid in this condition by rendering the mucous secretion more fluid through its nauseating action. But its effects must be carefully watched, as the preparations seem to vary in strength, and alarming symptoms and even fatal results have sometimes followed its use. In any case it is inferior to atropine and its allies in this condition. Nicotine and the other members of the group are not used in therapeutics.

Tobacco.

Tobacco had been in use among the aboriginal tribes of America before they became known to civilization. It was introduced into

Europe soon after the discovery of America, and its use as an article of luxury, beginning in England, soon spread to the continent, and in spite of papal bulls and numerous efforts on the part of the secular authorities, has continued to enthral a considerable portion of the human race. The most widespread use of tobacco—smoking—is also the most ancient one, having been that of the aboriginal Indians. Snuff-taking, introduced by Francis II. of France, remained fashionable for a long time, but is now almost obsolete. Tobacco-chewing is a more modern development, but shows no signs of abatement. Curiously enough, the leaves of the pituri plant, which contain nicotine, are formed into a mass and chewed by the natives of Australia. In smoking, snuffing or chewing, nicotine is absorbed; tobacco smoke always contains nicotine, though the amount varies with different kinds of tobacco and also with the way in which it is smoked; but a large proportion of that contained in tobacco passes over in the smoke along with pyridine and some of its derivatives. In snuff the nicotine is generally small in amount, while in chewing tobacco there is generally a varying amount of foreign matter, such as molasses.

The enjoyment derived from the use of tobacco has never been adequately explained, and it is not even proved that nicotine is essential to the pleasurable results; consideration of the pharmacological effects of nicotine gives no clue, for these are of the opposite nature. It has been suggested that smoking gives repose and thereby improves intellectual work, but this is denied by many habitual smokers. It has also been stated, and denied, that the mental energy is reduced by the use of tobacco, and an attempt has been made to demonstrate this by measuring the amount of work done with and without tobacco; but investigators are not agreed on the results, which probably depend largely upon the individual. One fact is certain, that the tobacco habit cannot be compared with the use of such drugs as morphine, cocaine, or alcohol, for it is not taken with the purpose of producing stimulation or depression of the central nervous system, and it seems doubtful whether the nicotine ordinarily absorbed really has any action whatsoever. Perhaps the local effects on the mouth, nose and throat play a larger part in the effects of tobacco than is generally recognized. A certain amount of rhythmic movement demanding no exertion seems in itself to have a soothing, pleasure-giving effect, for it is otherwise impossible to explain the satisfaction enjoyed by many in chewing tasteless objects, such as gum or straws. A curious fact which tends to show that tobacco smoking is not carried on for the sake of the nicotine absorbed, is that the pleasure derived from a pipe or cigar is abolished for many persons if the smoke it not seen, as when it is smoked in the dark; and very few blind men enjoy smoking.

Most people may indulge in the moderate use of tobacco for many years with perfect impunity, but its excessive use is followed in many individuals by a number of symptoms, some of them trivial, others indicating grave changes in important organs.

One of the commonest effects of overindulgence in tobacco is a

chronic inflammation of the throat and upper parts of the respiratory passages, leading to hoarseness and excessive secretion of the mucous glands. This is explained by the constant application to the throat of an irritant, alkaline vapor, and is probably not due to the specific action of nicotine. A similar irritated condition of the tongue is frequently met with, more especially when the hot vapor is constantly directed on one part, as in pipe smoking, and it is sometimes stated that the constant irritation thus produced renders the tongue and lip more liable to cancerous disease. Dyspepsia, want of appetite, and consequent loss of flesh may also be explained by the local irritation produced by the nicotine swallowed in the saliva. A symptom ascribed to the abuse of tobacco is palpitation and irregularity of the heart, which has been attributed to changes in the inhibitory mechanism. Another important symptom is dimness of vision, especially for colors, and imperfect accommodation, which may go on to complete blindness in one or both eyes. In early cases the retina often appears pale, and if the condition persists, atrophy of the optic nerve may result, probably following on degenerative changes in the ganglion cells of the macular region of the retina. This tobacco amblyopia is held by some to occur only when the tobacco habit is accompanied by alcoholic excess. Smoking causes a slight rise of blood-pressure in some individuals, and this has aroused apprehensions that it may tend to favor arteriosclerosis, but the change is so slight that these fears are quite groundless. Nervous symptoms, such as tremor, exaggeration of the reflexes, headache and giddiness, are sometimes developed in workmen in tobacco factories, but they do not seem to be induced by smoking or chewing tobacco, though depression, muscular weakness and giddiness are sometimes complained of. In the great majority of cases of chronic tobacco poisoning, the symptoms disappear on abandoning the habit, or even on restricting the daily consumption. A series of subjective and even objective symptoms are said to be induced in neurotic subjects by the sudden withdrawal of tobacco.

Esser has recently stated that chronic nicotine poisoning in animals induces marked disturbance of the heart, and that degeneration of the vagus fibres is recognizable histologically; changes have also been found in the nerve cells of the spinal cord and sympathetic ganglia similar to those described under chronic alcoholic poisoning.

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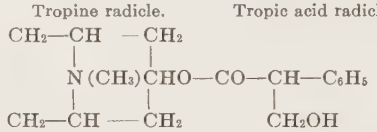
XI. THE ATROPINE SERIES.

The atropine series contains a number of very closely allied alkaloids of which the chief are *Atropine, Hyoscyamine* and *Hyoscine* or *Scopolamine.* They are found in many plants of the Solanaceæ order, and in most cases several of them occur together.

Atropine ($C_{17}H_{23}O_3N$) may be broken up by alkalies into an alkaloid, *Tropine,* and *Tropic Acid.* The former is a pyridine compound very closely allied to *Ecgonine* (see Cocaine) as may be seen by its structural formula, while the latter is an aromatic acid.

Atropine.

Tropine radicle. Tropic acid radicle.



Atropine is racemic hyoscyamine, that is, it consists of equal parts of lævohyoscyamine and dextrohyoscyamine, but, as the latter is only feebly active in the body, the action of atropine is practically that of its lævohyoscyamine half. Lævohyoscyamine is formed in the plants, and is readily changed to atropine in the plant cells and also in the process of extraction, so that the relative proportion of the isomers in the plants and in the preparations varies.

Hyoscine, or *Scopolamine,* was formerly supposed to be another isomer of atropine, but has lately been shown to differ slightly in its formula, which is $C_{17}H_{21}NO_4$. It is very closely allied to atropine, and is decomposed into tropic acid and *Scopoline* (*Oscine*), which is nearly related to tropine.

A number of other alkaloids have been described in different plants, generally associated with one or more of those already mentioned. But on examination these have generally proved to be mixtures of atropine, hyoscyamine and hyoscine. Thus the *Duboisine* of Duboisia myoporoides, the *Mandragorine* of Mandragora (Mandrake) and the *Daturine* of Datura stramonium have all failed to maintain their position as new bases and have proved to be mixures of the established alkaloids in varying proportions. *Atropamine, Belladonnine* or *Apoatropine* is found along with atropine in some plants (belladonna), and may be formed artificially from atropine by the removal of a molecule of water; it is a compound of tropine and atropic acid. *Pseudo-hyoscyamine* is said to differ from atropine and hyoscyamine in some of its chemical relations, but has not been the subject of much work as yet. *Atroscine* is isomeric with hyoscine and the same relation exists between them as between atropine and hyoscyamine.

After atropine had been found to be a compound of tropine and tropic acid, a number of other acids were attached to tropine in the same way as tropic acid. These artificial alkaloids are known as *Tropeines*, and in action resemble atropine in some points while differing from it in others. The only artificial tropeine which has as yet been used in medicine is the compound of tropine and oxytoluic acid known as *Homatropine*. *Scopoleines* have been formed by substituting other acids for the tropic acid of scopolamine, but none of them have proved of value in therapeutics as yet.

It must be understood that the combination of tropine and its allies with tropic acid does not partake in any way of the nature of the combination of an ordinary alkaloid, such as morphine, with an acid. The bond is the much closer one seen in the compound ethers, and the resulting substance is alkaline and combines with acids to form salts exactly as other alkaloids do.

The chief plants containing these alkaloids are Atropa Belladonna (Deadly nightshade), Hyoscyamus niger (Henbane), and Datura Stramonium (Thornapple).

Of less importance are Duboisia myoporoides, Scopola atropoides, and Mandragora autumnalis, or Atropa mandragora (Mandrake); another species of Duboisia contains nicotine.

A number of other Solanaceæ—*e. g.*, tobacco and potato leaves, are said to contain small quantities of the atropine alkaloids but the quantity present here is too small to be of any importance.

These alkaloids all resemble each other closely in the effects produced by them in animals. Some differences in the symptoms exist, however, and the action of atropine alone will first be described and later the points in which that of hyoscyamine and of hyoscine differ from it.

Atropine acts as a stimulant to the central nervous system and also affects a number of peripheral organs; in some of these the changes are due to the interruption of nerve paths, while in others these remain intact under atropine.

Symptoms.—In man $\frac{1}{100}$ gr. (0.6 mg.), causes some dryness of the mouth and throat, and thirst; the skin also feels dry, and the heart may be accelerated after a short period of slowing. Doses of $\frac{1}{25}$ gr. (2.5 mgs.) are followed by marked dryness of the skin and throat, thirst, difficulty in swallowing and hoarseness in speaking. There is often nausea, and in some cases vomiting, headache, and giddiness; the pupils are wider than normal and the sight may be indistinct, especially for near objects. The respiration may be quicker and the pulse often beats at one hundred per minute or more. A symptom that is often present, though by no means invariably so, is redness of the skin, more especially of the head and neck; the conjunctiva may also be congested. After larger doses the same symptoms are observed, but are soon followed by others of graver import. The patient can no longer swallow, although suffering from intense thirst, the heart is generally extremely rapid, speech

is difficult and hoarse, and the pupils are dilated until the iris almost disappears. Restlessness and garrulity point to an increase in the irritability of the brain; the patient at first talks in a perfectly normal way but soon becomes confused, begins a sentence and does not finish it, often bursts into laughter or sobs, and in short becomes delirious and eventually maniacal. Often marked tremor of different muscles may be observed, and eventually convulsions set in and may be the cause of death through the failure of the respiration. As a general rule, however, the stage of excitement passes into one of depression, the patient sinks into a sleep, which deepens into stupor and coma, the respiration and heart become slow, weak and irregular, and death eventually occurs from asphyxia.

In the frog the injection of small quantities of atropine is followed by a period of depression and paralysis of the peripheral nerve terminations resembling that seen under curara; after a few days there supervenes a stage of increased reflex excitability and tonic convulsions indistinguishable from those seen under strychnine. This stage slowly passes off and the animal again becomes normal.

Action.—These symptoms in man and other mammals, indicate stimulation of the **Central Nervous System** followed by depression. Those observed in man sometimes resemble those seen in the excitement stage of alcohol poisoning, and it has been suggested that in both the cause is rather a lessening of the control normally exercised by the higher powers over the lower motor areas than a true stimulation of the latter. But this is shown to be incorrect by the fact that in atropine poisoning the motor area is more easily stimulated by the electric current than normally. The stimulant action of atropine is also seen in the increased reflex response to irritation of the skin, as well as in the augmented activity of the centres in the medulla. The nervous symptoms under atropine, therefore, arise from true stimulation of the central nervous system, but they are wholly different from those produced by strychnine, because the latter acts more especially on the lower parts of the nervous axis, while atropine acts more strongly on the higher divisions. The most marked symptoms of strychnine poisoning arise from the spinal cord and medulla oblongata, and consist in increased reflex movements and convulsions, while those caused by atropine are rather to be referred to the brain, and consist in increased coördinated movements, such as talking and delirium, the exaggerated reflex being of minor importance.

Atropine differs from caffeine, on the other hand, in its effect on the brain, for under the latter the psychical functions are those affected first of all. It would seem probable, then, that each of these three stimulates the whole of the central nervous system more or less, but that while strychnine acts more strongly on the lower divisions, the spinal cord and medulla, and caffeine on the highest functions, the psychical, atropine occupies a midway position, and exercises its chief action on the motor divisions of the brain. These are rendered so excitable that the controlling areas can no longer keep them in check,

and an increase in movement occurs somewhat resembling that seen when the controlling areas are depressed by alcohol. The stimulant action spreads downward when large quantities have been absorbed, and involves the medulla oblongata and spinal cord, so that symptoms resembling those seen in strychnine poisoning may make their appearance. After the stimulation has lasted some time, depression sets in and may go on to complete paralysis of the central nervous system, which is fatal to mammals through cessation of the respiration. Even during the stimulation stage some symptoms of depression are to be made out, exactly as has been described under strychnine.

The peripheral action of atropine involves a number of secretory glands, organs containing unstriped muscular tissue, and the heart.

Most of the **Secretions** are decreased by the application of atropine —salivary, gastric, pancreatic, mucus, and sweat. This is due, not to any action upon the secretory cells, but to the failure of nervous impulses. It has been investigated most carefully in the salivary glands, but enough work has been done on the others to show that the process is the same in all. The *secretion of saliva* in the normal animal seems to occur only when impulses reach the gland cells by one of two paths—through the chorda tympani, or through the cervical sympathetic fibres. If the chorda typani be divided and put on electrodes and a cannula be passed into Wharton's duct, a rapid flow occurs through it on stimulation of the nerve, which ceases or is very much diminished on stopping the stimulation. If now atropine be injected, stimulation causes no increase in the secretion, and atropine, therefore, seems to paralyze some part of the peripheral secretory apparatus. The chorda tympani passes through ganglion cells on its way to the gland cells, and the impulses might be hindered in their passages through these, as actually occurs under the action of some drugs. (See Fig. 25.) But this is not the explanation of the inefficiency of chorda stimulation, as is shown by the fact that if the electrodes be pushed into the hilus of the gland so as to stimulate the nerve fibres beyond the ganglia no secretion follows. Another explanation would be that the gland cells themselves are paralyzed by atropine, but this is shown not to be the case, for on stimulating the sympathetic, which supplies the same cells as the chorda tympani, the usual secretion follows. The site of action of atropine, therefore, seems to lie between the ganglion cells on the course of the chorda tympani and the secretory cells, that is, the point of attack is the terminations of the nerve fibres in the gland cells. The action is limited to certain definite terminations, for it has been noted already that the sympathetic secretory fibres are not paralyzed, and it was discovered by Heidenhain that the vasodilator fibres of the chorda tympani are not paralyzed by atropine. Stimulation of the nerve after atropine therefore induces no secretion, but the gland becomes red and swollen, and the blood escapes from the veins in larger quantity and in spurts in the same way as in the unpoisoned animal under chorda stimulation. Atropine, then, seems to select the terminations of the secretory fibres of the chorda tympani for paralysis and to leave all

others unaffected. The secretion of saliva seems to occur generally only on the arrival of impulses by way of the chorda tympani, so that on the paralysis of its terminations the secretion ceases entirely.

In the same way the other *glands of the mouth, throat, nose and respiratory passages* cease secreting after atropine, and the effect is the characteristic dryness of the mouth, the hoarseness of the voice, and the thirst and difficulty in swallowing complained of after its administration.

The secretion of the *gastric juice* has been shown to be diminished or entirely arrested by atropine, which paralyzes the terminations of the secretory fibres of the pneumogastric nerve in the stomach (Fig. 31, p. 345). The hydrochloric acid of the secretion is more reduced than either the pepsin or the fluid as a whole. The secretion of *pancreatic juice* is reduced after atropine, and stimulation of the pneumogastric has no effect on it, while in the normal animal it accelerates the flow. The secretion induced by the specific pancreatic hormone, secretin, continues, showing that atropine does not act on the cells of the pancreas, but only isolates them from the pneumogastric nerve. But as the formation of secretin depends on the passage of hydrochloric acid into the duodenum, and this is lessened by the action on the gastric glands, the pancreatic secretion is further reduced in this indirect way.[1] The secretion of *tears* is diminished by atropine, presumably from the interruption of the nervous connections of the lachrymal glands. The *bile* is also said to be somewhat lessened by atropine. The interchange of glycogen and sugar in the liver is not affected by atropine according to recent investigations (McGuigan), but on the other hand some forms of hyperglycæmia seem to be lessened by it.

The same paralysis is produced in the terminations of the nerves in the *sweat glands*. Stimulation of the sciatic nerve as a general rule causes perspiration in the foot of the cat and dog, but after atropine this effect is absent, because the impulses cannot reach the cells through the paralyzed terminations, and the skin therefore becomes dry and hot. The local application of atropine to the skin has no effect on the sweat secretion, as it does not penetrate to the glands. The secretion of *milk* is not materially changed by atropine, whether the alkaloid is carried to it by the blood or is applied locally. This is in accord with the physiological observation that the mammary gland continues to secrete after all its nerves have been cut and allowed to degenerate; in other words the mammary secretion is largely independent of the central nervous system.

The *kidney* is not controlled by secretory nerves, and atropine causes little or no change in the amount of urine except through the arrest of the other secretions. The *secretion of lymph* is not altered by atropine, so that it also is not controlled by nerves in the same way as the true

[1] In the dog large doses of atropine are said to cause the secretion of a dilute pancreatic secretion with a low content of ferment.

The prolonged use of atropine sometimes has led to weakness and malnutrition perhaps from the insufficiency of the digestive juices.

secretions. The secretion of the suprarenal glands is not affected by atropine though it is controlled by nerves more directly.

All **Organs Containing Unstriped Muscle** (apart from the arterial wall) seem to be altered by atropine. Thus the movements of the pupil and œsophagus (except in animals in which these consist of striped muscle), stomach, intestine, bladder, uterus, spleen and thoracic duct are affected by atropine.

FIG. 26

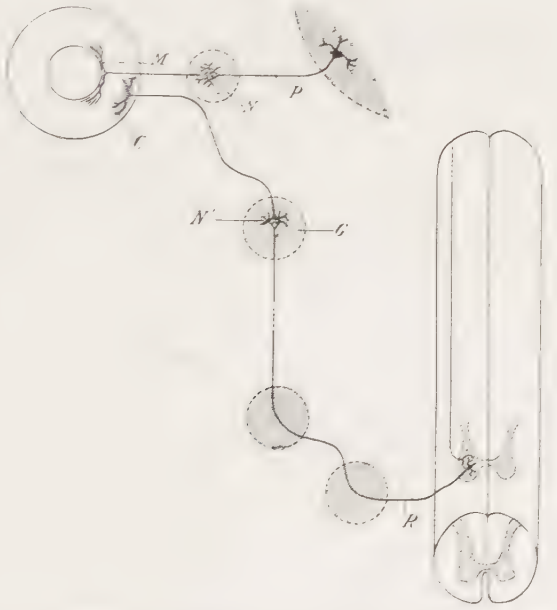


Diagram of the innervation of the iris. *P*, a fibre of the motor oculi passing from the brain to the ciliary ganglion (*N*), in which it terminates around a nerve cell, which sends an axis cylinder to terminate, *M*, in the circular fibres of the iris. *R*, a sympathetic nerve fibre issuing from the lower cervical cord, running through the stellate and inferior cervical ganglia and terminating around a ganglion cell in the superior cervical ganglion, *G*. The axis cylinder from this nerve cell runs to the iris (passing the ciliary ganglion) and terminates, *C*, on the radiating fibres. *M* is the point acted on by atropine and muscarine. *N*,*N'*, the ganglion cells, are the seat of action of nicotine. *C*, the terminations in the dilator fibres, that of adrenaline.

The dilatation of the *pupil* occurs on internal administration as well as on the application of minute quantities locally, and is due to paralysis of the myoneural junctions in the circular muscle of the iris. This is shown by the fact that stimulation of the motor oculi nerve or of the postganglionic fibres from the ciliary ganglion is without effect. This limits the paralysis to the periphery, and that the muscle is not acted on is shown by its reacting to electrical stimulation. The local nature of the action may be further shown by carefully applying a minute quantity of the drug to one side of the cornea, when dilatation of one half or less of the pupil occurs, the rest remaining contracted. The motor oculi (Fig. 26) constantly transmits impulses through the

ciliary nerves to the sphincter muscle of the iris and keeps the pupil moderately contracted, and when these impulses can no longer reach the iris owing to the interruption of the path, the sphincter relaxes and the pupil dilates. The contractile substance does not seem to be affected by the ordinary application of atropine, but if strong solutions be continuously applied, it may be paralyzed by it as by many other drugs. Atropine antagonizes the action of pilocarpine in the pupil after degeneration of the motor oculi, and the receptor for these alkaloids therefore does not undergo degeneration and must be situated in the muscle between the nerve ends and the contractile substance.

The constrictor muscle is constantly opposed by dilator fibres, and when the former is thrown out of activity by the paralysis of the terminations of the motor oculi, the radiating fibres cause an active dilatation. If, however, the radiating muscular fibres be separated from their innervating centre by section of the cervical sympathetic nerve in the neck, they also cease to contract and there is no active dilatation, so that atropine causes less widening of the pupil than it would if impulses continued to reach the radiating muscle. After the application of atropine to the eye, the iris often relaxes with sufficient force to tear weak adhesions to the lens, and if the iris be attached at two points to the lens, atropine causes a bow-shaped dilatation between them, the concavity being directed inward. The dilatation is therefore an active movement, accomplished by the contraction of the radiating muscular fibres, but these are not put in motion by the action of atropine on the radiating muscles of the iris, or their nerves, but by the normal impulses descending from the central nervous system, which after atropine are not counterbalanced by impulses reaching the circular fibres.

The dilatation of the pupil effected by atropine is not quite maximal, for stimulation of the cervical sympathetic trunk generally increases it, though but slightly. It differs considerably in different animals, being more complete in man, the dog and the cat than in the rabbit, entirely absent in birds and reptiles, and elicited with difficulty in the frog. In birds and reptiles the iris consists of striped muscle fibres, and accordingly atropine has no action on the nerve terminations.

When complete dilatation is attained, the pupil ceases to contract in bright light, as the impulses descending from the central nervous system are prevented from reaching the muscle, although the rest of the reflex arc is intact. The retina is unprotected from bright light and this often gives rise to pain and discomfort in the eyes and headache.

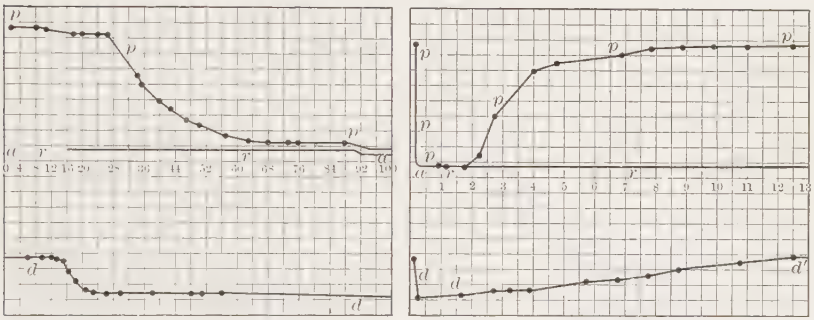
Besides the dilatation of the pupil, a further result of the application of atropine to the eye is the paralysis of the *accommodation*. Near objects are no longer seen clearly, while distant ones are as distinct as formerly or may be even more distinct in some eyes. The action is here again on the myoneural junction, in this case in the ciliary muscle. On local application the relaxation of the lens occurs later, and disappears earlier than the dilatation of the pupil, and larger quantities are required to produce it.

The *intraocular pressure* appears to be unchanged by atropine in the

normal eye, but when there is a tendency to hypernormal pressure, atropine often augments it considerably whether it is applied locally or is carried to the eye by the circulation. This is apparently the indirect result of the dilation of the pupil, by which the lymph outflow is obstructed; in the normal eye this is not sufficient to raise the pressure, but in eyes in which the outflow is already deficient the additional hindrance may suffice to increase the tension and precipitate an attack of glaucoma.

The *bronchial muscle* normally contracts when the pneumogastric nerve is stimulated, but makes no response after atropine, which paralyzes the myoneural terminations; the sympathetic fibres which inhibit the bronchial muscle and dilate the bronchi are unaffected by atropine.

FIG. 27 FIG. 28



Charts of the changes in the accommodation (*pp*) and in the pupil (*dd*) under atropine The impairment of the accommodation and the widening of the pupil are indicated by downward movements of the lines, while the return to the normal is shown by an upward movement. In Fig. 27 the time from the application of atropine is given in minutes to show the beginning of the action; in Fig. 28 the time is in days to show the gradual recovery. (After Donders.)

The terminations of the nerves in the unstriped muscle of the *œsophagus* are affected in the same way as in the bronchial muscle. A curious contrast has been noted by Luchsinger in the behavior of the œsophagus in rabbits and cats, in the former of which the muscle is striated, while in the latter the upper part is striated, the lower is unstriated. Atropine, he found, paralyzes the vagus in those parts which are unstriped, while leaving unaffected those in which the fibres are striped. Exactly the opposite occurs after curara, which paralyzes the nerve supply of the striped muscle, while leaving the unstriped active.

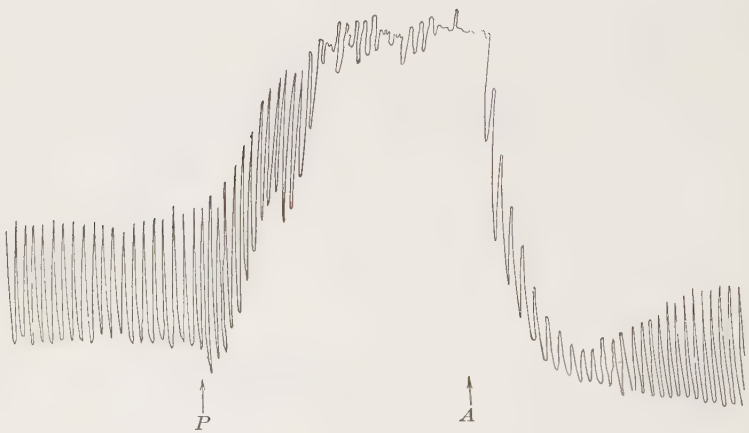
It is possible that the difficulty in swallowing, which is present in cases of poisoning by atropine, may be due in part to the paralysis of the motor nerve, but it is generally attributed to the absence of the mucous secretion and consequent dryness of the passages.

Atropine has generally a sedative effect on the movements of the *stomach* and *intestine*, though vomiting has sometimes been observed

in cases of poisoning, and less often free evacuation of the contents of the bowel. After very small quantities the normal peristalsis is not affected, and the movement induced by ordinary doses of the purgatives is not arrested, but the griping pains resulting from large doses or from the more violent purgatives are absent or less marked if atropine is given along with them. Similarly, the violent peristaltic and tetanic contractions seen after such poisons as pilocarpine and muscarine are prevented by the preliminary injection of atropine.

These results suggested that atropine paralyzes the terminations of some of the extrinsic nerves of the stomach and bowel in the same way as it paralyzes the oculomotor terminations in the iris. But this proves to be incorrect, for the vagus and splanchnic nerves continue to exert their ordinary influence after atropine. In fact, these small

FIG. 29



Movements of the intestine. At *P*, pilocarpine causes a violent tetanic contraction, which is maintained until at *A* atropine is applied, when the spasm is immediately relieved. The normal pendulum movements continue afterwards. (Magnus.)

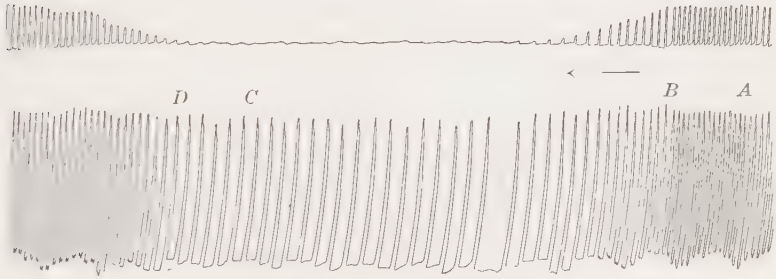
doses of atropine appear to arrest only certain abnormal violent forms of contraction, and as they do this without interfering with the normal peristalsis and without interrupting the path of nervous impulses from the brain to the bowel, it must be accepted that these abnormal forms arise from some mechanism which is distinct from that presiding over the ordinary peristalsis, and which does not lie on the path of the nerve impulses.

This action on abnormal contractions is the only one induced by therapeutic doses of atropine, but in animal experiments large quantities tend to increase the peristalsis from some action exerted on the plexus of Auerbach (Magnus). It is possible that this increased peristalsis may account for the vomiting and purging sometimes seen in cases of poisoning. Finally, very large quantities paralyze the muscle fibres, but this probably does not occur in the intact animal.

Atropine exercises the same sedative effect on the movements of other organs as on those of the bowel. Thus, the *spleen, uterus, gall-bladder, ureters, urinary bladder* and the *other ducts* of the genito-urinary tract react like the stomach and bowel, several poisons failing to induce contractions after atropine, while stimulation of the nerves continues to be effective. It has been observed frequently in cases of poisoning that the urine is ejected soon after the ingestion of the poison, and subsequently there is a desire to micturate without the ability to do so.

Atropine paralyzes the **Inhibitory Terminations of the Vagus in the Heart**, and stimulation of this nerve therefore causes no change in the pulse after its administration. Nicotine in large doses also removes the inhibitory power of the vagus, but acts on a different part of the nerve, namely, on the ganglia. That atropine does not act here but on the terminations has been shown by a number of observations. Thus, in the normal frog's heart, and even after paralysis of the ganglia on the course of the vagus, electrical stimulation of the venous

FIG. 30



Tracings of the ventricle (lower) and auricle (upper) of the dog's heart. During systole the levers moved upward; during diastole, downward. At *A*, the heart was normal; at *B*, the inhibitory fibres were stimulated electrically, and this was continued throughout the tracing. The ventricular rhythm became slow and irregular, while the auricle stood still in diastole. At *C*, atropine sulphate was injected into a vein, and at *D* the effects of the inhibition began to pass off, although the stimulation was continued.

sinus causes slowing and standstill of the heart, because the stimulus reaches the postganglionic nerve fibres (Fig. 24, p. 314); but after atropine, no slowing follows stimulation of the sinus. Again, several drugs stimulate the ends of the vagus in the heart and act on parts in which no ganglia exist, but these drugs have no effect whatever after atropine. Small quantities of atropine have no further action on the heart than the paralysis of the inhibitory nerve ends. The terminations of the accelerator nerve are unaffected, exactly as the terminations of the sympathetic in the salivary glands, and the heart muscle is neither stimulated nor depressed. The heart is therefore placed in the same position as if the vagus were divided in the neck, and, accordingly, it is accelerated in some animals, while in others the rhythm is unchanged. In the dog there is marked quickening of the heart after atropine, because normally impulses are constantly

transmitted from the inhibitory centre in the medulla, and these prevent the heart from beating as rapidly as it would if freed from the nervous control. In the cat the tone of the vagus is less, and the changes produced by atropine are correspondingly smaller, while in the rabbit and frog there is generally no inhibitory retardation of the heart, and atropine therefore produces little change. In man the effects vary considerably with the age of the patient. The inhibitory fibres seem almost inactive at birth, but their tone increases with age up to twenty-five to thirty-five years, and from this time lessens again. Atropine does not quicken the heart in the newborn child, but up to about thirty the acceleration increases with the age, and from this point onwards it lessens again until the heart is accelerated by only 4 to 5 beats per minute in patients between eighty and ninety years. Along with the acceleration of the pulse the other effects of vagus section are also produced—increase in the extent of systole, decrease in the diastole and augmentation of the output of the heart per minute.

Stimulation of the vagus causes no retardation of the pulse after an ordinary dose of atropine, but, on the contrary, is not infrequently followed by acceleration from the presence of accelerator fibres which are not affected by atropine. But it is found that if a minimal amount of atropine is given, so that slight vagus stimulation has no effect, a very strong current may still slow the heart; the terminations are so weakened that feeble impulses fail to reach the heart, but strong impulses can still force their way through the block. (Pilcher and Sollmann.)

Large quantities of atropine, besides paralyzing the vagus, weaken and depress the heart muscle, and the contractions consequently become slower and weaker and the output of the heart is less than normal. Even therapeutic doses injected hypodermically in man slow the pulse for a short time, apparently from direct action on the heart muscle; the first effect is thus a fall in the pulse rate followed by marked acceleration.

The **Peripheral Action** of therapeutic doses of atropine is due to its paralyzing receptors in a number of organs. Some of these are normally put in action by nerve impulses, which they transmit to the contractile or secretory cells, and their paralysis by atropine leads to the failure of part of the nervous control of the organ (many glands, pupil, bronchial muscle, œsophagus, and heart). In other organs the receptors do not lie in the path of nerve impulses and their paralysis by atropine therefore does not affect the nervous control of these organs (muscle of stomach, intestine, spleen, uterus, and bladder). The effects of atropine on these organs is in fact only detected by the cessation of unusual movements induced by certain poisons and by some pathological conditions (see also muscarine and pilocarpine, p. 346). The organs thus affected receive their innervation from the autonomic system, some of them from the parasympathetic division, some others from the sympathetic; atropine cannot be said to affect either of these divisions exclusively, but its action on the myoneural junctions of the parasympathetic division is more prominent than that on the sympathetic. The increasing difficulty in reconciling the action of atropine with the view that it is exerted on hypothetical myoneural

receptors has led to the suggestion that the alkaloid may really affect the muscle cells directly, but this theory is not more easily brought into accord with the facts than the older and more generally accepted one.

The voluntary **Muscles** are not directly affected by atropine. An action similar to that of curara is seen in the frog under large doses, and evidence of a similar action in mammals is offered by the fact that the twitching induced by physostigmine through its action on the myoneural junctions is antagonized by atropine; but no true curara action is induced by atropine in mammals.

The terminations of the **Sensory Nerves** are depressed by its local application. Thus, when atropine is applied to an irritated surface of the skin or to a mucous membrane, numbness is produced and the sensation of pain is lessened; no such effect occurs when atropine ointment is rubbed on the unbroken skin and the local anæsthetic effect is not elicited by its internal administration.

Circulation.—The changes in the circulation under atropine arise for the most part from the changes in the heart. The blood-pressure often falls for a few minutes at first from the direct action on the heart muscle and then rises above the normal from the acceleration when this is marked. But the rise in pressure from the acceleration is not great unless there is unusual activity of the inhibitory mechanism previously. There is no evidence that the vasoconstrictor centre in the medulla is excited by atropine, and although concentrated solutions of atropine perfused through the vessels cause them to dilate from action on their walls, this does not occur in the living animal.[1] Very large amounts of atropine depress the heart and consequently the blood-pressure falls; the respiration fails in cases of poisoning before the heart is seriously injured. In poisoning there is often flushing of the skin of the head and neck and a rash resembling that of scarlet fever, and these have been regarded as due to dilatation of the arterioles from stimulation of the vasodilator centre; the flush is said to disappear on section of the cervical sympathetic cord, which would suggest its central origin. The rash usually disappears after a few hours, but is sometimes followed in a day or two by desquamation.

The action of atropine on the **Respiration** has been the subject of much discussion. In therapeutic doses, its only effect is to relax the bronchi, and the respiratory centre is unaffected; larger amounts accelerate the breathing from stimulation of the centre and increased formation of carbon dioxide. In severe poisoning this quickened breathing is frequently interrupted by convulsive movements, and such an interruption often proves to be final. If it returns, the move-

[1] In normal animals there is thus no evidence that atropine acts on the vessels or on the nerve ends in them; but in animals whose vessels are dilated by acetylcholine atropine immediately counteracts this effect, which indicates that it possesses some vascular action. The vasomotor nerves continue unimpaired in their effects, so that the antagonism appears to be exerted on some receptor which does not lie on the path of the nervous impulses (*Cf.* the action on the stomach above). On the other hand it is stated that the frog's vessels contracted by adrenaline are relaxed by atropine through an action on the terminations of the vasoconstrictor nerves.

ments become shallower and slower in the stage of depression of the nervous centres, and the failure of the respiration is the cause of death in fatal cases of poisoning.

Atropine often induces a marked rise in **Temperature,** the cause of which cannot be said to be definitely known. According to Ott the dissipation of heat is increased, but the heat formation undergoes a still greater augmentation. This seems to be independent of the circulatory changes and also of the convulsions, and is attributed by him to direct action on the heat centres of the brain.

Distribution and Excretion.—Atropine is rapidly absorbed and may be found in most organs. It is excreted in the urine in man and most animals, partly as unchanged atropine, partly broken up into tropine; from a third to a half of that ingested reappears in the urine, and traces have been found in the milk and also in the fœtal blood. The rest of the atropine undergoes oxidation in the body, apparently in the liver; in some rabbits, which show a very high congenital tolerance, much of the atropine ingested undergoes decomposition in the blood plasma, apparently through the action of a ferment. In other rabbits no such action occurs in the blood and these do not acquire this power even when treated for a long time with atropine; they may be endowed with it however, by the injection of the serum of an animal which already possesses it, and even cats which do not normally destroy atropine in the plasma, are also enabled to do so by the injection of the active serum of a rabbit (Schinz); the blood of man, the dog and many other animals does not seem to possess this property.

Tolerance.—Most animals withstand much larger quantities of atropine than man, and an especial degree of tolerance is met with in the herbivora; rabbits, for example, may be fed for weeks on belladonna leaves without showing any symptoms; this is undoubtedly the result of the active decomposition of the alkaloid which occurs in their plasma. It has also been observed that the action of atropine on the heart and other organs passes off more quickly in rabbits than in other animals and this again arises from the atropine being destroyed so rapidly. A certain degree of tolerance may be acquired by other animals through the continued administration of atropine, which ceases to elicit the symptoms from the central nervous system in the doses previously sufficient and later seems to have a weaker and shorter action on the peripheral organs. In chronic poisoning with atropine in animals, there is often marked salivation developed; this is said to be the result of a state of increased excitation of the centres controlling the salivary secretion in the medulla oblongata, the impulses from these reaching the glands either by way of the chorda tympani or by the sympathetic nerves; there is some evidence that a similar excessive secretion occurs in the pancreas (Arima).

Hyoscyamine is rarely obtainable in pure form, as it is almost always mixed with atropine, into which it changes when kept in solution and perhaps even when dry. It paralyzes the same peripheral mechanisms as atropine, but acts almost exactly twice as strongly on them. Its

action on the central nervous system in mammals resembles that of atropine and the fatal dose is the same, but in the frog it has less tendency to cause convulsions. No narcotic influence is exercised on either frogs or mammals; the belief that it induces sleep is founded on observations in which hyoscine was mixed with the hyoscyamine employed.

The action of atropine, as has been stated, is compounded of that of natural, or lævorotary, hyoscyamine with that of its dextrorotary isomer. The latter does not exist free in nature and possesses little or no action on the nerve terminations, while it stimulates the spinal cord of the frog more than either atropine or hyoscyamine. The peripheral action of atropine is thus due to its containing hyoscyamine, and as a grain of atropine contains only half a grain of hyoscyamine the former naturally exercises only half the effect of a grain of hyoscyamine. On the other hand, the half grain of dextrorotary hyoscyamine in a grain of atropine is almost inert on the nerve terminations, but exercises the same effect on the central nervous system as its lævorotary complement. Atropine thus acts on the central nervous system in mammals in the same strength as hyoscyamine, but only half as strongly in the periphery.

Scopolamine, or **Hyoscine**, resembles atropine closely in its peripheral action, except that it passes off more quickly. The inhibitory terminations in the heart are paralyzed; but the therapeutic dose in man is too small to elicit this effect, and the pulse is therefore unaltered in rate or may be slower, owing to the hypnotic action. Applied to the conjunctiva it produces mydriasis and loss of accommodation more quickly than atropine, but for a much shorter time; pure hyoscine acts about twice as strongly on the nerve terminations as atropine, or about equally strongly with hyoscyamine. The effects on the central nervous system present the greatest divergences from those described under atropine, for the characteristic stimulation is absent in the great majority of cases. As a general rule, scopolamine produces a marked sensation of fatigue and drowsiness, the patient moves about less and speaks less, and a condition in no way dissimilar to the natural sleep follows. In many cases, however, a short stage of excitement with giddiness, uncertain movements and difficult and indistinct speech precedes sleep, and occasionally symptoms exactly resembling those produced by atropine follow the administration of hyoscine, especially if large doses are employed. Sleep generally lasts from five to eight hours, and the patient may then remain quiet for several hours longer. As a general rule, after small doses no confusion is complained of on awakening, but dryness of the throat and thirst are often present. Larger doses do not cause deeper sleep but give rise to delirium and excitement resembling those following atropine. In one or two cases collapse has been observed after scopolamine. The respiratory centre does not seem to be stimulated as by atropine, the respiration generally becoming slower from the beginning.

In the lower mammals scopolamine reduces the excitability of the motor areas as tested by electric shocks, while the reflex excitability in the frog is not increased as by atropine. Hyoscine appears to be

excreted or destroyed in the tissues much more rapidly than atropine, for its effects last a shorter time.

The action of hyoscine, then, seems to correspond with that of atropine, save that the central nervous system is here depressed, while the action on the peripheral nerve ends is shorter. It depresses the brain in very small quantities, $\frac{1}{2}$ mg. ($\frac{1}{120}$ gr.) being generally sufficient to induce quiet. It does not seem to be so dangerous as the others of the series, for over half a gramme ($7\frac{1}{2}$ grs.) administered to a small cat did not kill the animal. A certain degree of tolerance is produced after repeated use, so that the dose has to be increased after a week or two.

Hyoscine is much less reliable as a hypnotic than morphine or the members of the chloral group. It is most effective when sleep is prevented by motor excitement, and the sleep seems to arise from the relief of this condition and not from depression of the consciousness.

Hyoscine is lævorotary to polarized light; the racemic form, which is often present in commercial hyoscine, acts only one-half as strongly on the peripheral organs, because in it the lævorotary alkaloid is mixed with the dextrorotary isomer, which is almost inactive. The cerebral action is equal, however, in the two forms.

The other natural alkaloids have been less carefully examined than the three foregoing and possess no therapeutic interest.

Among the artificial tropeines only one has received much attention at the hands of either experimental or practical therapeutists. This is **Homatropine**, a compound of tropine and oxytoluic acid, which resembles atropine in its action, but is much less poisonous. When applied to the eye, it dilates the pupil almost as rapidly as atropine, but less completely, and the action passes off much sooner. It has less tendency to increase the intraocular tension than atropine owing to its shorter action.

Methylatropine or **Eumydrine**, an artificial compound of atropine, acts rather more strongly than atropine on the peripheral organs. It has been used to some extent in ophthalmology.

The other tropeines vary in their action on the lower animals, some of them failing to act on the peripheral organs, while others have the peripheral action of atropine but in a weaker degree; the compounds of tropine with the acids of the methane series possess much less peripheral atropine action than the others. The peripheral action is most developed in the compounds of tropine with acids of the benzene series possessing hydroxyl and an asymmetric carbon atom, the whole molecule being lævorotary. A considerable variation also exists in the effects of the tropeines on the central nervous system, some causing excitement like atropine, while others act as depressants and therefore resemble hyoscine.

Tropine itself is a weakly toxic, basic substance, which in large quantities stimulates the frog's heart, but does not paralyze the vagus nor the oculomotor terminations on local application. After the injection of large quantities, dilatation of the pupil has been observed, it is true, but this does not seem to be of the same origin as that produced by atropine.

Some artificial scopoleines have been found devoid of action on the nerve ends

in the pupil and heart and on the salivary secretion. They possess a certain stimulant effect on the heart muscle like some of the artificial tropeines, and all produce more or less depression of the central nervous system and narcosis.

The action of the **Crude Drugs** is very similar to that of the active principles already discussed. The peripheral action of all of them is therefore almost identical in kind, though varying in degree. In considering their effects on the central nervous system it must be remembered that those containing much atropine are more stimulant, those with hyoscine more sedative. But as the relative amount of the different alkaloids changes with various conditions such as the age of the plant and the methods of preparation, it is obvious that accurate results can be obtained only by the use of the pure principles. Even when a preparation is accurately standardized in the content of alkaloids, as in the U. S. P. and B. P., its power may vary very widely according to the proportion of lævorotary alkaloid (hyoscyamine) to racemic (atropine).

Preparations.

U. S. P.—**Belladonnæ Folia**, the leaves of Atropa Belladonna, containing 0.3 per cent. of mydriatic alkaloids. Dose, 0.06 G. (1 gr.).

Extractum Belladonnæ Foliorum (1.25 per cent.), 0.015 G. ($\frac{1}{4}$ gr.).

Tinctura Belladonnæ Foliorum (0.03 per cent.), 0.75 mil (12 mins.).

Belladonnæ Radix, the root of Atropa Belladonna, containing 0.45 per cent. of alkaloids. Dose, 0.045 G. ($\frac{3}{4}$ gr.).

Hyoscyamus, the leaves of Hyoscyamus niger, henbane (0.065 per cent. of alkaloids). Dose, 0.25 G. (4 grs.).

Extractum Hyoscyami (0.25 per cent. of alkaloids), 0.06 G. (1 gr.).

Tinctura Hyoscyami (0.007 per cent. of alkaloids), 2 mils (30 mins.).

B. P.—**Belladonnæ Folia**, the fresh leaves and branches of Atropa Belladonna, containing 0.3 per cent. of alkaloids.

Belladonnæ Radix, the root of Atropa Belladonna.

Extractum Belladonnæ Siccum (1 per cent. of alkaloids), $\frac{1}{4}$–1 gr.

Tinctura Belladonnæ (0.035 per cent. alkaloids), 5–15 mins.

Hyoscyami Folia, the fresh leaves, flowers and branches of Hyoscyamus niger, henbane.

Extractum Hyoscyami (0.3 per cent. alkaloids), 2–8 grs.

Tinctura Hyoscyami, $\frac{1}{2}$–1 fl. dr.

Alkaloids.

Atropinæ Sulphas (U. S. P., B. P.), a white crystalline powder, with a very bitter taste, soluble in water and alcohol Dose, 0.0005 G. ($\frac{1}{120}$ gr.).

Liquor Atropinæ Sulphatis (B. P.), 1 per cent., $\frac{1}{2}$–1 min.

Lamellæ Atropinæ (B. P.), gelatin discs, each containing $\frac{1}{300}$ gr. of atropine sulphate.

Hyoscyamine is not procurable in even approximately pure form and might well be dispensed with, as it offers no advantages over atropine. The sulphate and hydrobromide have been used in the same dose as atropine.

Hyoscinæ Hydrobromidum (B. P.), Scopolaminæ Hydrobromidum (U. S. P.) ($C_{17}H_{21}NO_4HBr,3H_2O$), the hydrobromide of hyoscine or scopolamine. It is obtained from hyoscyamus, scopola and other Solanaceæ, and forms colorless, transparent crystals with an acrid, bitter taste, and is very soluble in water, less so in alcohol. 0.3 mg. ($\frac{1}{200}$ gr.); B. P., $\frac{1}{200}$–$\frac{1}{100}$ gr.

Homatropinæ Hydrobromidum (U. S. P., B. P.), ($C_{16}H_{21}NO_3HBr$) the hydrobromide of an alkaloid prepared from tropine by condensation with

mandelic (oxytoluic) acid, a white crystalline powder soluble in 6 parts of cold water.

Lamellæ Homatropinæ (B. P.), gelatin discs, each weighing $\frac{1}{30}$ gr. and containing $\frac{1}{100}$ gr. of homatropine hydrobromide.

Methylatropinæ Nitras or ***Eumydrin*** (unofficial) an alkaloid prepared from atropine, forms a white crystalline salt readily soluble in water. Dose 1–3 mg. ($\frac{1}{50}$–$\frac{1}{20}$ gr.).

Therapeutic Uses.—The numerous changes produced by atropine and its congeners on the organism would indicate for them a very wide sphere of usefulness were it possible to elicit their action on one organ without affecting others, and this difficulty may perhaps be overcome in the future, when the different individuals of the series have been more carefully compared, and new tropeines and other modifications of the tropine radical are available in therapeutics.

The peripheral action of the whole series, as far as it is at present known, is so uniform that any member might be used to elicit it, but the only one that has come into general use for its peripheral effects is atropine. The purposes for which atropine is employed may be divided into groups as follows:

To Arrest or Lessen Secretions.—In rare cases of excessive *salivation* atropine has proved of service, but it is much more frequently used to lessen the *perspiration*, especially in the later stages of phthisis. For this purpose comparatively small quantities, such as $\frac{1}{4}$ mg. ($\frac{1}{250}$ gr.) given by the mouth or hypodermically, are generally sufficient, or the extract or tincture of belladonna may be used instead; eumydrin has also been employed for this purpose in somewhat larger doses than atropine. In local sweating, atropine is often applied locally in the form of an ointment, liniment, or plaster, although Tappeiner has found that it has no effect when thus employed. It is also used to arrest the secretion of the *milk*, a belladonna plaster being strapped over the gland, but this acts merely as a mechanical support and the same result follows the application of simple adhesive plaster. Some forms of excessive secretion of *gastric juice* have been treated by atropine with success.

To Paralyze the Cardiac Inhibitory Terminations.—For this purpose a slightly larger quantity is required than is necessary to stop the secretions, and the administration of sufficient atropine to paralyze the vagus (1 mg.) therefore involves unpleasant dryness of the throat and difficulty in swallowing. In cases where slowing of the heart tends to be dangerous in itself, more especially in poisoning with muscarine, pilocarpine and their allies, atropine is indicated. It may also be used for diagnostic purposes, to find if bradycardia is due to disease of the heart muscle or to inhibition. It may be repeated here that the resultant quickening is much less in old than in middle-aged people, and in many cases of old aortic lesion the administration of atropine is followed by little acceleration. Some forms of intermission of the pulse are due to unusual activity of the inhibitory apparatus, and these may be remedied by atropine; but this intermission possesses little importance, and seems to require no therapeutic treatment.

Atropine may be used to diagnose it from the more significant forms present in organic disease of the heart. In typhoid fever atropine accelerates the pulse comparatively little owing to the heart muscle being involved in the action of the toxin; the injection of atropine may thus be used as a means of diagnosis from other fevers (Marris). The use of atropine to paralyze the vagus terminations before the administration of an anæsthetic has been discussed already. (See p. 226.)

To Paralyze the Terminations of the Motor Nerves in the Iris and Ciliary Muscles.—It is used for this purpose largely in ophthalmology as a means of diagnosis and of treatment, and the precise conditions in which it is indicated may be treated better in text-books on this subject than here. For these objects, solutions of the alkaloidal salts are generally applied to the conjunctiva, when enough of the alkaloid diffuses into the eye to produce marked local effects without affecting more distant organs. In order to dilate the pupil, extremely dilute solutions are used; a few drops of a solution of 1 in 1000, or even of 1 in 10,000 are quite sufficient. Much stronger solutions are required to paralyze the accommodation, and as a general rule 1 per cent. is used. These strong solutions produce complete paralysis in one to one and a half hours, and the accommodation does not recover completely until after five to seven days, while the pupil may not regain its normal size for ten to fourteen days. The application of even weaker atropine solution renders the sight imperfect for an inconveniently long period, and hyoscine and homatropine are therefore much used in its stead. The symptoms produced by a 1 per cent. solution of homatropine pass off, or at any rate become very much less marked in the course of thirty-six hours. These are consequently preferable for diagnostic purposes, while atropine is rather to be used where it is desirable to produce a paralysis of longer duration, as in various inflammatory conditions of the iris or cornea. Atropine is also preferable where complete paralysis of the accommodation is necessary, as homatropine often fails to effect this. Atropine and its congeners are contraindicated where there is any suspicion of glaucoma, as, owing to their action on the intraocular pressure, they may either aggravate the disease already present or precipitate an acute attack.

When dilatation of the pupil is necessary and there is reason to apprehend the results on the intraocular pressure, homatropine should be employed, as its effects can be readily controlled by eserine. Numerous cases of poisoning have arisen from the extensive use of atropine in diseased conditions of the eye. It is often asserted that it passes down with the tears through the lachrymal duct and is absorbed from the nose, throat and stomach, but as a matter of fact it may be absorbed from the conjunctiva itself. The symptoms are generally only the milder ones of atropine poisoning—dryness of the throat and slight excitement—but dangerous and even fatal poisoning has also arisen from its local application. In many cases this is due to the application of unnecessarily strong solutions to the eye, but, on the other hand, some patients seem abnormally sensitive to the action of

atropine, and hyoscine 0.5 per cent. or homatropine, ought to be preferred. In rare cases a curious inflammatory condition of the conjunctiva is set up by atropine, and this is often supposed to be due to the use of irritant preparations, but sometimes seems to follow the application of the absolutely pure alkaloid, and is apparently an idiosyncrasy; it may, perhaps, be explained by the arrest of the ordinary secretions of the lachrymal gland and conjunctiva in these cases. Sometimes discs of gelatin impregnated with atropine or homatropine (B. P.) are applied to the conjunctiva instead of solutions of the salts. Eumydrine 1 per cent. may be substituted for homatropine in ophthalmology, but offers no advantages.

To Relax Spasm of the Stomach and Intestines.—In various forms of colic atropine is of very great service in lessening pain and allowing the passage of the intestinal contents; for instance, it is preferable to morphine in lead colic, as it does not cause constipation. It sometimes relieves the pain of gastric ulcer by preventing the reflex contraction of the stomach wall, and similarly spasmodic contraction of the pylorus may be released. Hernia and volvulus are sometimes reduced by atropine injected hypodermically (3 mg. or $\frac{1}{20}$ gr.). It is often prescribed along with purgatives in order to lessen the griping which they produce, and has been used as a laxative in some forms of constipation with considerable success. For action on the bowel it is generally prescribed in pill form as one of the extracts of belladonna or hyoscyamus. The object of prescribing an impure preparation instead of the alkaloid is to allow of a strong local action on the intestinal wall along with a slow and imperfect absorption, as the pure alkaloidal salts are liable to be absorbed in the duodenum.

To Relax Spasms of the Involuntary Muscles of Other Organs.—In the spasmodic contraction of the ureters and bile ducts due to calculi, atropine is occasionally prescribed either in the form of a pill or in solution for internal use, or by hypodermic application. In some forms of asthma due to contraction of the bronchial muscles, atropine has been applied locally by means of a spray or given internally, and stramonium leaves are often found of benefit when made up into cigarettes and inhaled when the attack comes on;[1] the smoke has been shown to contain small quantities of the alkaloids. Some cases of asthma are said to have been permanently cured by treatment with atropine internally. An ointment of atropine has also been applied to the cervix uteri with the hope of relaxing spasm during labor, but the results are somewhat questionable. Perhaps this action in relaxing spasmodic contractions may also explain the beneficial effects obtained in cases of incontinence of urine in children, in which belladonna has long been the most reliable remedy.

To Lessen Pain.—Belladonna liniment, plaster and ointment have long enjoyed a considerable reputation as local anodynes, and atropine

[1] Another ingredient of these asthma cigarettes is often nitrate of potassium, which is reduced to nitrite in the course of combustion and passing into the lungs in this form dilates the bronchi by action on the bronchial muscle.

has not infrequently been injected into painful areas. This anodyne action is very weak compared with that of cocaine, however, and the preparations of atropine have been less used of late years.

The Effects on the Central Nervous System of the members of this group are very different, and the purposes for which they are used are diametrically opposed. Atropine is used as a stimulant in various conditions of depression of the brain and medulla oblongata. Thus, in collapse its hypodermic injection has been advocated to stimulate the respiration and at the same time to free the heart from excessive inhibition. In dangerous poisoning from narcotic and hypnotic drugs, more especially in opium poisoning, atropine has been largely used. A long and weary dispute as to the value of atropine in those cases has been carried on, the general results of which suggest that it is possible to increase the activity of the respiratory centre by atropine in opium poisoning, but only by the use of small quantities (1.5 mg. or $\frac{1}{40}$ gr.), as large doses, such as have frequently been advised, tend to depress the central nervous system and thus to aid rather than to antagonize the action of morphine on the respiration. It may be questioned whether in any case atropine may not be replaced by caffeine with advantage. The former stimulates the medullary centres, but subsequently paralyzes them, while caffeine, even in comparatively large quantities, does not seem to have a depressant action in man.

Atropine at one time had some reputation in the treatment of epilepsy. It has been shown both clinically and experimentally that this reputation was undeserved, the number of attacks and their violence being rather increased than diminished by its exhibition; the belief in its powers arose from the use of impure preparations containing hyoscine.

In some spasmodic diseases, such as whooping-cough, belladonna preparations have long enjoyed a wide reputation; this may possibly be explained either by the hyoscine reducing the excitability of the respiratory centre, or by atropine relaxing bronchial spasm.

Hyoscine, or scopolamine, has been used as a narcotic to depress the central nervous system; it is of great efficacy in insanity, producing sound and refreshing sleep, but is of less value in controlling the excitement during the day, and may in fact increase it. Hyoscine is also used with benefit in various forms of tremor of central origin, and is said to lessen sexual excitement. Its hypnotic action does not seem to be of the same nature as that of opium, for in sleeplessness produced by pain it is of comparatively little value, and it has no power to relieve pain itself. It differs from chloral in not inducing deep sleep, for patients under the influence of hyoscine can always be aroused and are much less confused than after chloral. The special indications for hyoscine seem to be sleeplessness due to abnormal activity of the motor areas and some forms of tremor.

On the use of hyoscine with morphine as a surgical anæsthetic see p. 262.

Poisoning.—In cases of poisoning with belladonna and its allies the treatment is purely symptomatic. In the excitement stage sedatives may be used; perhaps chloroform and ether are best, as their effects are more transient than the others. Morphine has been advised, but its action on the respiratory centre renders its use dangerous, as in severe atropine poisoning the stimulation soon passes into depression, and the effects of the poison and its so-called antidote therefore supplement each other. Chloroform and ether, on the other hand, may be used to control the spasms and then stopped when these pass off. In the depression stage caffeine may be used, and eventually artificial respiration. Pilocarpine is of course useless, as it does not antagonize atropine in the brain, which is the point of danger.

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Compare also the Literature of pilocarpine and muscarine, nicotine, and physostigmine.

Agaricin.

White Agaric (Agaricus albus, Boletus Laricis), a fungus growing on the European larch tree, was formerly a purgative and antihydrotic of some repute. Its use to lessen the perspiration (antihydrotic) has been revived of late years, or rather a preparation known as agaricin and containing the active principle has been introduced into therapeutics. Agaric acid, the active constituent is cetylcitric acid ($C_{19}H_{36}OH(COOH)_3$).

Action.—Both the acid and its sodium salt irritate the mucous membranes and wounded surfaces, and cause inflammation and even suppuration when injected subcutaneously. Large quantities irritate the stomach and intestine and cause vomiting and purging, but these are more liable to arise from the

impure agaricin owing to its containing resinous acids. Injected into the frog, agaric acid paralyzes the central nervous system, slows the heart, and stops the secretion of the skin glands. In mammals the intravenous injection of agaric acid is followed by depression, weakness, dyspnœa, and death. The medulla oblongata is first stimulated and then paralyzed, as is shown by the blood-pressure first rising and then falling to zero, while the heart is primarily slowed by inhibitory action and later regains its rhythm, eventually to fail after the arrest of the breathing. Applied to surviving organs, agarate of sodium causes contraction and increased tone of involuntary muscle and systolic contracture of the frog's heart. Animals can only be poisoned with difficulty by the subcutaneous injection of agaricin, and no general symptoms are elicited when it is administered by the mouth. The action resembles that of the saponin series, except as regards the sweat secretion.

The most interesting feature of the action of agaric salts is the arrest of the sweat secretion, which is caused by peripheral action, for stimulation of the nerves of the cat's foot fails to elicit perspiration after its ingestion. It thus acts on the same peripheral mechanism as atropine in all probability, that is, on the terminations of the secretory nerves, but differs from atropine in acting only in the sweat glands, for the saliva, tears and other secretions are not hindered by it, and may, in fact, be increased by its causing nausea. It is also devoid of action on the nerve terminations in the heart and pupil. Atropine acts much more powerfully than agaric acid, at least twenty times as much of the latter being required to arrest the sweat secretion.

Uses.—Agaricin is used in the night sweats of phthisis and other similar conditions and is generally given in pill form in doses of 5 60 mgs. ($\frac{1}{12}$–1 gr.). The commercial agaricin often contains a large percentage of impurities and has to be given in larger quantities, but the treatment ought to be begun with small doses. Tolerance is said to be acquired after some time, and the dose has then to be increased. The best results are got when the pills are taken five to six hours before retiring, as the acid is only slowly absorbed. If agaricin causes intestinal irritation and diarrhœa, it may be given with opium, but as in phthisis all irritation of the bowel is to be avoided, the remedy ought perhaps to be stopped when any such disturbance arises. Camphoric acid, which was formerly advised to lessen the secretion of sweat in phthisis, appears to have little or no effect and should be discarded (Vejux–Tyrode).

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XII. PILOCARPINE AND MUSCARINE.

Pilocarpine and muscarine, two alkaloids of very different chemical constitution, possess similar properties from a pharmacological point of view. *Pilocarpine* ($C_{11}H_{16}N_2O_2$) is found along with *Isopilocarpine* in the leaves of several species of Pilocarpus.[1] The chemical formula of *Muscarine,* the alkaloid of the poisonous mushrooms Amanita muscaria (Agaricus muscarius) and Inocybe is unknown.

Choline ($HO—N(CH_3)_3CH_2CH_2OH$) and its esters resemble muscarine in action so closely that choline-nitrite ether was formerly known

[1] *Pilocarpidine* has been isolated from the leaves of Pilocarpus Jaborandi only, and is practically inert. *Jaborine* was formerly stated to occur with pilocarpine and to possess an action resembling that of atropine, but more recent investigators have failed to confirm either of these statements.

as synthetic muscarine, and natural muscarine was confidently believed to be a choline compound, Choline is a comparatively weak poison but its acetyl ester injected intravenously in the dose of one four-hundred-millionth of a milligram reduces the blood-pressure of a cat.

Arecoline ($C_8H_{13}NO_2$), one of the alkaloids contained in Betel Nut (Areca catechu), resembles pilocarpine in its action but is more powerful.

Pilocarpine and muscarine act on the same peripheral organs and apparently on the same receptive substances as atropine, but they arouse these receptors to activity, while atropine depresses them. The receptors may lie on the path of impulses from the nerves to the contractile or secretory substance, and the effect of pilocarpine and muscarine is then identical with that of nerve stimulation (p. 332).

Symptoms.—The symptoms of poisoning in man commence with a very marked secretion of saliva, soon followed by excessive perspiration and a flow of tears. After muscarine and sometimes after pilocarpine, nausea, retching and vomiting, pain in the abdomen and violent movement of the intestines causing profuse watery evacuations, are next observed. The pulse is sometimes quickened, sometimes very slow and irregular; the pupil is contracted, and the sight is accommodated for near objects. The respiration is often quick and dyspnœic, and rales may be heard over the bronchi, denoting an accumulation of mucus in them. Giddiness and confusion of ideas are complained of, and after pilocarpine tremors and feeble convulsive movements are sometimes observed, but the nervous symptoms are not so conspicuous as those from the peripheral organs. Eventually the respiration becomes slower and great weakness in the movements manifests itself, but the consciousness remains more or less perfect till the breathing ceases.

Action.—The salivary and lachrymal **Glands**, the mucous glands of the mouth, throat, nose and deeper respiratory passages, the gastric secretory glands, the pancreas, and probably the intestinal glands, all secrete copiously after muscarine and pilocarpine. The sweat glands and the ceruminous glands of the ears are likewise roused to unwonted activity, and many other glandular structures are also stimulated.[1] There is evidence that the suprarenal glands respond to pilocarpine with an increased secretion of adrenaline into the blood, and this explains some anomalous reactions met with under pilocarpine.

In most cases the solids of the secretions are increased as well as the fluids, although to a somewhat less extent. The bile, the urine and the milk do not seem to be affected directly by pilocarpine and muscarine, although they may be reduced in amount or otherwise modified by the withdrawal of large quantities of fluid from the body by other channels.

After a small quantity of atropine, pilocarpine and muscarine in ordinary quantities produce no increase in any of the secretions. This indicates that the seat of action of these poisons is not the secretory

[1] A curious example of this has been shown by Dreser to occur in the fish, in which the swimming bladder secretes more oxygen than usual.

cells, for it has been shown that atropine paralyzes only the myoneural junctions and leaves the cells uninjured. On the other hand, section of the secretory nerves does not alter materially the action of pilocarpine or muscarine, for the secretion of perspiration in the foot of the cat is increased by pilocarpine even after section of the sciatic nerve.[1] The seat of action of pilocarpine and muscarine is therefore the myoneural connections between the nerves and the epithelial cells. These are stimulated by the members of this group and paralyzed by atropine, these two series being mutual antagonists.

FIG. 31

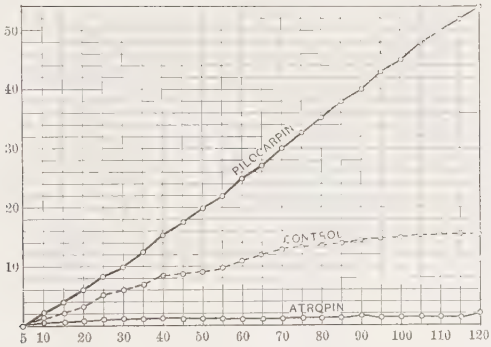

Chart of the gastric secretion in the dog under pilocarpine and atropine. Three observations were made: in one milk alone was given, in another milk with pilocarpine, and in a third milk with atropine. The amount of secretion was noted in a small isolated pouch of the stomach, and is indicated graphically in the chart. (Riegel.)

The salivary secretion may amount to half a litre or more in the course of two or three hours after an injection of pilocarpine, while the skin and lungs excrete even a larger quantity of fluid in the same time. The weight is thus considerably reduced by pilocarpine owing to the loss of fluid, which may, according to some authors, amount to 2·4 kilogrammes ($4\frac{1}{2}$–9 lbs.) after a single dose.

The secretion of the milk is not increased by pilocarpine, and this accords with the view that the mammary gland possesses no true secretory nerves.

The increased activity of the glands is accompanied by an acceleration of the blood current through them, but this is a result of their stimulation from any cause whatever, and is probably not due to the direct action of the alkaloids on the vessels. The redness of the skin,

[1] In man it is found that after division of a nerve pilocarpine in small doses no longer causes perspiration in the limb. And in cases of complete interruption of the nervous paths in the cord, small doses of pilocarpine cause no sweating in the lower part of the body. This does not seem due to the division of the secretory fibres proper, for division of the sympathetic nerves alone does not impair the sweating under pilocarpine; more probably the failure of pilocarpine to cause sweating in these cases arises from the disturbance of the circulation through the break in the sensory and vasodilator path (Burn).

especially of the face, so often observed after pilocarpine, may perhaps be explained in this way, as an accompaniment of the augmented activity of the sweat glands.

Muscle.—Nausea and discomfort in the *stomach*, followed by retching and vomiting, are rarely seen after pilocarpine, but form some of the earliest symptoms of muscarine poisoning. They are not produced by the saliva swallowed, as was formerly supposed, but by the action of the alkaloids on the stomach, and as these symptoms are removed by atropine in small quantities, it is inferred that pilocarpine and muscarine act on the same receptors as atropine, but in the opposite sense, stimulating instead of paralyzing them. These receptors do not appear to lie in the path of nerve impulses in the stomach, as is shown by the gastric muscle still responding to stimulation of the vagus after the receptors are paralyzed by atropine.

The *intestines* are also set in unusually active movement by a similar process, and repeated evacuation of their contents follows. These are at first of firm consistency, but later, as the continued peristalsis carries down the contents of the small intestine, which have not lain long enough in the bowel to allow of the absorption of their fluid, the fæces contain more water than usual. This fluidity of the stools may also be due in part to an augmentation of the intestinal secretion, but this has not been satisfactorily demonstrated. Even after the bowel has been completely evacuated, the persistent peristalsis betrays itself in painful straining. (See Fig. 29, p. 330.)

The muscle of a number of other organs contracts after pilocarpine or muscarine from stimulation of receptors similar to those in the stomach and bowel. Thus the *spleen*, *bladder*, *ureters*, and pregnant *uterus* are contracted, and in the case of the bladder repeated evacuation and straining may occur. In some animals the uterus is inhibited by pilocarpine and muscarine, this being the usual action in the non-pregnant cat.

In some other forms of muscle, pilocarpine and muscarine cause contraction by acting on receptors which lie on the path of the nerve impulses. Thus in poisoning with these and also on local application, the *pupil* becomes extremely narrowed, and at the same time the *ciliary muscle* contracts so that the lens is accommodated for short distances. Both of these phenomena are due to stimulation of the myoneural junctions in the intraocular muscles (Fig. 26, p. 327), for atropine removes the contraction and at the same time interrupts the passage of impulses from the nerve to the muscle. Pilocarpine continues to act after the anatomical ends of the nerves have degenerated, so that the point of action is probably a receptor interpolated between the actual end of the nerve fibre and the contractile substance of the muscle; that the contractile substance is not affected is shown by its continuing to contract after atropine has paralyzed the pilocarpine receptor.

The intraocular pressure is reduced by muscarine and pilocarpine, although they may increase it at first. This is due to the iris being

drawn up by its contraction and thus allowing free egress to the intraocular fluids (see Atropine, p. 329).

The *bronchial muscles* are contracted by pilocarpine and muscarine, which here also appear to act on myoneural receptors at the terminations of the pneumogastric nerves.

All these muscular phenomena are prevented by the previous administration of atropine. This antagonistic action has been carefully studied in the eye, where it is found that after pilocarpine has produced contraction of the pupil, the administration of very small quantities of atropine is followed by dilatation. Strong pilocarpine solution again dropped into the eye will again reduce the size of the pupil, but the quantity required is vastly more than in the normal eye, and this second contraction may again be removed by comparatively small quantities of atropine. In the bird's pupil, in which the muscle is striated, muscarine and pilocarpine have no effect, the terminations of the nerves being evidently different from those in mammals.

The action of pilocarpine and muscarine on the **Circulation** presents some differences in different species of animals. On the application of either to the frog's heart, its rhythm is at once slowed, the diastolic pause being much increased in length and the contractions lessened in force. Soon the heart ceases to beat entirely, although irritation of its muscle by mechanical or chemical means elicits one or more contractions. The symptoms produced are exactly those seen on stimulation of the vagus by electrical shocks, and muscarine has long been believed to act by stimulation of the inhibitory mechanism in the heart. The point of action is not the ganglia on the inhibitory fibres, for muscarine is effective after these are completely paralyzed by nicotine, and it also acts on the apex of the frog's ventricle, in which no ganglia whatever have been found. The action must therefore be localized at some point between the ganglia and the actual contractile substance, for the latter maintains its normal character responding with contractions to stimuli. Muscarine is therefore generally held to stimulate the myoneural junctions between the inhibitory fibres and the contractile substance of the muscle. Atropine removes this standstill by paralyzing the junctions, but larger quantities of muscarine or pilocarpine will again overcome the atropine action and restore the standstill or, at any rate, the slow pulse. Digitalin and its allies remove the standstill by increasing the irritability of the muscle until the inhibition can no longer hold the heart in check, but throughout the rhythm caused by these the activity of the vagus can be seen in the slowness of the beat and the prolongation of the diastole. When the heart is slowed by muscarine, stimulation of the vagus is more effective than normally, the action of the drug being added to that of the electrical stimulus.

In rabbits and cats similar changes are seen in the circulation after muscarine. The heart is slowed or brought to a complete standstill, the blood pressure falls, and all the symptoms produced by anæmia of the brain may follow, but the animal becomes again perfectly normal on the administration of small quantities of atropine. Pilocarpine

differs from muscarine here in several particulars, for it soon depresses the inhibitory fibres and the heart regains its former rhythm, but the cardiac muscle is then affected, so that the contractions rapidly become weaker and slower again, and this secondary slowing is not removed by atropine; the vasomotor centre also becomes gradually weakened by large doses, so that the bloodvessels remain somewhat dilated, and the arterial tension remains low even after atropine.

In dogs the stimulation of the inhibitory fibres seems sometimes to be entirely absent after pilocarpine and muscarine, and in man this is very frequently the case. Instead of a slow pulse and lessened tension of the arteries, acceleration and increased blood-pressure are then observed. This is accompanied in man by marked palpitation and

FIG. 32

Tracings of the movement of the auricle (upper) and ventricle (lower) of the dog under muscarine. During contraction the levers move upwards; during relaxation downwards. *A–B*, normal. At *B*, muscarine was injected intravenously and at *C* it began to act. The movements of the ventricles are slower and a distinct pause is seen in diastole. The contraction is less complete, while the heart relaxes more than usual during diastole. The auricle soon comes to a standstill in diastole. Compare the effects of stimulation of the vagus in the first part of Fig. 30, page 331.

discomfort in the region of the heart and by dilatation of the skin vessels, especially of those of the face. In other cases, however, the same circulatory disturbances are produced as in the cat and rabbit (Fig. 32). The acceleration of the heart and palpitation may perhaps arise from the nausea, which may be sufficient to overcome the inhibitory stimulation.

In embryo hearts muscarine, in ordinary quantities, produces no change whatever during the first one hundred and fifty hours of life (in the chick). The explanation of this phenomenon is that the inhibitory nerves have not been developed at this stage, and after their development is complete, muscarine acts on the heart as in the adult. The absence of slowing in some of the invertebrates may be due to a similar

cause, although this does not hold good for the crab, in which there is a well-defined inhibitory apparatus but in which muscarine causes acceleration.

Peripheral Action.—Muscarine and its allies have generally been regarded as acting on the terminations of a series of autonomic nerves, chiefly belonging to the craniosacral division, but, on the other hand, some observers have held that the action is a direct one on the organs themselves and that the nerves are not involved. The arguments in favor of the action on the nerve ends have been the exact similarity in the effects of vagus stimulation and of muscarine in the heart and the fact that drugs, such as atropine, which paralyze the nerves, also antagonize muscarine. The second argument is weakened by the observation that the muscarine action on such organs as the intestine and uterus can be abolished by atropine, though it has no effect on the results of nerve stimulation, so that the seat of action of muscarine and atropine cannot lie on the path of the nerve impulses in these organs. The similarity in the action of muscarine and of nervous stimulation is so great, however, that the receptive substance for the alkaloid must be closely connected with the nerve path and must undergo the same seasonal and other changes as the myoneural connections. It is possible, however, that both muscarine and nerve stimulation may affect the same process and that the parallelism in their effects may be explained in this way; for example, if a change in the permeability of the membranes of a cell is the essential feature of nerve action, muscarine may also have this result while atropine may oppose this muscarine action. In the case of the salivary gland cells, atropine opposes not only the action of muscarine in increasing the permeability but also that of the nerve impulse, while in the intestine atropine neutralizes the action of muscarine but not that of the nerve impulse: in each case the drugs act on some structure different from the actual motor or secretory substance and also different from the anatomical nerve ends. The increase in the adrenaline secretion under pilocarpine and its allies complicates the action of the latter, for the effects are diametrically opposed in many organs.

According to Straub, muscarine acts on the heart only as it penetrates into the muscle cells, and once arrived in the interior has no further action. If dilute solutions are applied to the heart, the alkaloid may slowly accumulate in the muscle without the heart being arrested. If now the muscarine be extracted from the muscle and applied to another heart in concentrated solution, this second heart is immediately arrested. The action therefore depends on the concentration in which the drug is applied and not on the amount in the muscle; in other words, the action is exerted in the process of absorption and not after absorption. Straub holds that atropine opposes muscarine by retarding its permeation into the cell and thus producing the same result as if the concentration of the muscarine solution were lessened. On adding more muscarine so as to render the solution very concentrated the permeation is accelerated in spite of the atropine, and the muscarine action reappears.

The **Respiratory** centre is not acted on directly by small quantities of pilocarpine and muscarine. But the changes in the circulation lessen the amount of blood passing through the lungs, and the contraction of the bronchial muscle may seriously retard the movement of the air and thus impair the aëration of the blood. The œdema of the lungs which is often observed in cats and rabbits poisoned with the members of this series, and which has also occurred in fatal poisoning in man, arises from the slowing of the circulation through the lungs from the cardiac action. Large quantities of pilocarpine cause a tendency to convulsive movements and a more rapid and labored

respiration. Eventually the respiration becomes slow and weak and asphyxia follows.

It has been found that pilocarpine increases the **Leucocytes** of the blood from its acting on the spleen and other leucocyte-forming tissues; it is possible that the leucocytes are pressed out of the spleen by the contractions of the smooth muscle. Both polymorphonuclear and mononuclear cells are increased in the blood. Ruzicka states that the Malpighian corpuscles of the spleen are increased in number after pilocarpine.

The **Temperature** is said to be increased by pilocarpine, although only to a very small extent, and the carbonic acid excretion is increased through the drug increasing the activity of the glands and other organs. After the perspiration is fully developed the internal temperature is generally reduced, especially in fever.

Some symptoms occur in cases of poisoning which point to some action of the alkaloids on the **Central Nervous System.** Thus frogs develop well-marked convulsions, and even in the higher animals and man tremor and slight convulsive movements, such as hiccough, have been observed. The collapse which is seen in the later stages may be central in origin but probably is largely the result of the peripheral action, and the convulsions, which occur in some cases, arise from anæmia of the brain as the result of the cardiac weakness.

Pilocarpine and muscarine, while resembling each other in general, present some points of difference, which are of the greatest importance as regards their use in therapeutics. Muscarine has practically never been introduced into medical practice, because, while its action on the secretions is quite equal to that of pilocarpine, the gastric symptoms are produced more readily by it. It is also a more powerful poison than pilocarpine, and is not procurable in pure form.

Choline and its esters, while inducing all the typical effects of muscarine, have some farther actions. Thus they reduce the blood-pressure, not only by inhibiting the heart but also by dilating the bloodvessels; and this action is antagonized by atropine, which must thus be credited with a hitherto unrecognized action on the vasodilator mechanism of the peripheral vessels. After atropine the choline compounds contract the vessels from a stimulant action on the ganglia resembling that of nicotine, and like it they also affect the nerve ends in striated muscle in the opposite way from curara. Choline thus seems to combine the effects of muscarine and nicotine. It is of importance as it occurs in the tissues, and it is possible that it may sometimes lead to symptoms. It has indeed been suggested that choline compounds may be hormones acting on the parasympathetic nerve ends in the same way as adrenalin acts on the sympathetic nerve ends; thus it is sometimes regarded as the hormone of the intestinal movements, but this is far from being established. Some other trimethyl ammonium compounds resemble choline in inducing both the muscarine and the nicotine effects (Dale).

Pilocarpinæ Nitras (U. S. P., B. P.) ($C_{11}H_{16}N_2O_2HNO_3$), the nitrate of an alkaloid obtained from Pilocarpus leaves, forms a white crystalline powder, which is soluble in 8–9 parts of cold water, and is freely soluble in hot alcohol. 0.01 G. ($\frac{1}{6}$ gr.); B. P., $\frac{1}{20}$–$\frac{1}{5}$ gr.

Therapeutic Uses of Pilocarpine.—Its action on the sweat glands renders pilocarpine much the most powerful sudorific in the pharmacopœia, and it is used internally almost exclusively for this purpose. In various conditions in which excess of fluid accumulates in the body, pilocarpine may be exhibited to remove it. In dropsy, especially that due to renal disease, a few injections frequently reduce the fluid and remove the effects of the accumulation, although they do not, of course, affect the diseased tissues directly. By unburthening the blood and tissues of their excessive fluid, however, pilocarpine may improve the nutrition of the kidney, and thereby promote its recovery. In dropsy due to heart disease pilocarpine must be used with caution, owing to its action on the heart. In some other exudations pilocarpine has also been advised, as in pleural, pericardial, and subretinal effusion. It must be remembered that after the sweating produced by pilocarpine there usually sets in a period of depression, weakness and languor, and this may be sufficient to counteract the improvement obtained by the removal of the fluid. It is still a disputed point whether pilocarpine possesses any advantage as a sudorific over the other means of producing sweating, such as hot or cold packs. Its advocates point to the fact that much less disturbance of the patient is required, and that the subsequent depression is not greater, while its opponents assert that the hot or cold pack produces less depression and is not accompanied by the unpleasant salivation and occasional nausea of pilocarpine. Accumulations of fluid in the body may also be removed by way of the bowel by the use of a hydragogue cathartic or preferably a saline purgative, or the kidney may be stimulated to special activity by the use of such diuretics as theobromine and caffeine. The last method of treatment is that generally preferred as it induces less weakness and depression subsequently than either of the others. The sweating induced by pilocarpine is much more profuse than that seen after the nauseating diaphoretics such as ipecacuanha, and no such effects are claimed for pilocarpine as for these in chills and fever.

In uræmia pilocarpine sometimes proves of great benefit if exhibited early, and it has been supposed that this was due to the skin taking up the renal function vicariously and eliminating the poison. Some support has been given this explanation by the discovery of traces of urea in the perspiration after pilocarpine, but it is now recognized that the urea is not the poisonous principle in uræmia, and the beneficial effects are probably due rather to the removal of fluid and the relief of the overstrained circulation. It has also been suggested that pilocarpine acts directly on the kidney, and an increase in the urine is not infrequently seen after several injections; but this is to be ascribed rather to the changes in the circulation following the removal of the fluid than to any direct action on the renal epithelium, for which there does not exist any satisfactory experimental evidence.

In ophthalmic surgery pilocarpine has been employed as a substitute for physostigmine, to contract the pupil and reduce the intraocular pressure. For this purpose a dilute solution of the nitrate (2 per

cent.) may be used, or gelatin lamellæ may be prescribed, each containing $\frac{1}{4}$ mg. ($\frac{1}{250}$ gr.), to be laid on the conjunctiva. The contraction of the pupil generally attains its maximum in about one-half to one hour, and passes off in three to five hours; it is less complete and of shorter duration than that seen after physostigmine. Pilocarpine is said to first increase and then lower the intraocular tension.

In various diseases of the ear, pilocarpine has been used with good effects in some cases, but it is quite unknown how it acts here. The conditions in which it is of service are various forms of labyrinthine disease, and some forms of effusion into the tympanic cavity.

Pilocarpine was at one time used to cause contractions of the uterus in labor, and several cases of abortion have been ascribed to its use. Further experience has led to the conclusion, however, that in order to elicit this ecbolic action quantities are necessary which produce undesirable secondary symptoms.

Pilocarpine is frequently prescribed in lotions for the hair, and a renewed growth of the hair has been frequently seen in alopecia treated in this way. This has been explained by its action on the glands of the skin, increasing the moisture of the scalp and improving its circulation and nutrition, but Tappeiner found that the local application of pilocarpine to the skin produces no increase in the secretion of the glands.

In cases of atropine poisoning, the use of pilocarpine is quite unjustified as the danger arises from the central nervous system in which the action of atropine is not antagonized by pilocarpine. In poisoning from pilocarpine or muscarine small quantities of atropine are the antidote recommended alike by pharmacological experiment and by clinical experience.

Muscarine Intoxication.—In Siberia the Agaricus muscarius is used to form an intoxicating beverage. The symptoms produced are hilarity and jollity, and the victims declare themselves to be more capable of fatiguing exertions than they would be without the preparation. Eventually giddiness and somnolence are produced, and after large quantities vomiting and convulsive attacks may follow and eventually prove fatal. The exhilarating effects are probably due to the presence of a poison discovered by Harmsen and not to the muscarine. This new poison seems to play a rôle at least as important as that of muscarine in cases of amanita poisoning; it is not antagonized by atropine, and its chemical nature is unknown.

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[1] The literature of muscarine and pilocarpine is so mixed with that of atropine, nicotine, and physostigmine that a complete list would involve numerous repetitions. I must, therefore, refer those interested to the bibliography given under those groups, and shall mention here only the papers which deal very largely with muscarine and pilocarpine.

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XIII. PHYSOSTIGMINE.

Physostigmine or Eserine is the chief alkaloid of the Calabar bean, or Ordeal bean (Physostigma venenosum), which grows in Western Africa and was employed there by the natives in the trials by ordeal for witchcraft. Either physostigmine itself, or a nearly allied alkaloid, occurs also in the Kali or Cali nuts, the seeds of Mucuna urens. The constitution of physostigmine ($C_{15}H_{21}N_3O_2$) is still unknown.[1]

Physostigmine produces a number of symptoms resembling those of muscarine and pilocarpine poisoning; it stimulates the same organs, but may affect another set of receptors, and it has much less effect on the inhibitory nerves.

Symptoms.—The symptoms of poisoning vary but little in different animals; in the dog and rabbit the first results of a large dose of physostigmine are weakness in the voluntary movements and a curious tremor and muscular twitching, beginning in the hind legs, but soon extending over the whole body. The animal falls on one side and can not raise itself again, although it makes efforts to do so when touched. The saliva and tears are increased, the bowel is often evacuated and in the dog vomiting is common. The respiration is at first rapid and deep, and later slow and dyspnœic, the heart is weak and slow, and the pupil is contracted to a small point. These symptoms become more marked as more of the poison reaches the blood, until the respiration ceases. In cats these symptoms of depression and paralysis are preceded by a stage of increased movement and evident anxiety, but the later symptoms resemble those in the dog. In man physostigmine elicits practically the same results as in the dog, vomiting and pain in the stomach region, dyspnœa, giddiness and muscular weakness, contraction of the pupil, salivation, and perspiration. The heart

[1] A number of other alkaloids have been stated to occur in Calabar bean, but their existence is not sufficiently established in most cases and nothing is known of their action. They have been named *Calabarine*, *Isophysostigmine*, *Physovenine*, *Eseramine*, etc.

is slow, muscular twitching may be present and complete collapse follows. In frogs the voluntary movements disappear soon after the injection of physostigmine, the respiration ceases, and last of all the reflexes are paralyzed.

Central Nervous System.—In cases of poisoning in man, the consciousness is preserved until late, which indicates that the highest functions of the brain are not directly affected by physostigmine. The motor cerebral cortex is apparently rendered more excitable, for in epileptics the number and intensity of the seizures increase under its use, and in guinea-pigs rendered epileptic by operative procedures the same aggravation is seen after it. In the dog epileptiform convulsions occur occasionally, while in the cat a stage of excitement is generally present, and irregular muscular movements, such as nystagmus, are seen in these and other animals. It is possible, however, that some of these effects may arise from the peripheral action of the poison, for example from the partial asphyxia from broncho-constriction; they all disappear after the injection of atropine. The depression and muscular weakness which is seen in animals under large doses probably arise from affection of lower parts of the central nervous system and resemble the condition known as collapse more than that of narcosis.

Quite apart from these central effects, physostigmine causes twitching of the muscles which is not prevented by division of the nerves and is therefore peripheral in origin; this symptom is not marked in the frog, but may be so developed in mammals as to simulate convulsions. It is arrested by curara, but not by atropine, and does not occur in muscles whose nerve ends have degenerated after section of the nerve. This has suggested that physostigmine acts on the nerve plates rather than on the receptive substances intercalated between these and the contractile substance, which are the seat of action of curara and nicotine. But against this it may be urged that curara and physostigmine are mutual antagonists, for the paralysis of curara may be removed by physostigmine and on the other hand the twitching induced by physostigmine is arrested by curara; and this suggests that they act at the same point. Further investigation may determine the question.

The **Respiration** is at first somewhat accelerated and then becomes slow and weak. The preliminary acceleration may arise from central stimulation, or possibly from partial asphyxia due to constriction of the bronchi. The subsequent weakness and slowness of the breathing is undoubtedly of central origin, and death follows from the failure of the respiratory centre.

The changes in the **Circulation** require further investigation. Small doses slow the pulse and increase the blood-pressure, while larger are followed by greater slowing of the heart and a fall in the blood-pressure. The slowness of the pulse is due to the poison acting on the heart directly and not to any inhibitory interference, for it occurs after large quantities of atropine. According to several observers, the irritability of the terminations of the inhibitory fibres in the heart is increased, so that stimulation of the vagus is more effective after physostigmine. The

contractions of the heart do not seem to be altered in strength in mammals, though the rhythm is slower.

The increased blood-pressure has also been the subject of some discussion. It seems independent, in part at least, of the vasomotor centre, for it is not prevented by section of the spinal cord or of the splanchnic nerves, operations which prevent impulses from the centre reaching the vessels. It may be partly due to the powerful contraction of the intestines expelling the blood from the mesenteric area, or to direct action on the muscular coats of the arterioles causing contraction and thus narrowing their calibre, or perhaps to both of these, along with some increase in the activity of the vasomotor centre.

The frog's heart beats more slowly after physostigmine, but here the individual contractions are said to be strengthened and prolonged, and there is definite evidence of stimulation of the heart muscle, which is not seen in mammals. If the vagus be stimulated in the frog after physostigmine, it produces slowing but no complete standstill of the heart, because the irritability of the muscle is so much augmented that the inhibitory apparatus can no longer entirely control it. If such a poison as muscarine produces complete standstill, physostogmine removes it, not by depressing the inhibitory apparatus, but by increasing the irritability of the muscle.

The **Secretions** are increased by physostigmine as by pilocarpine and muscarine; thus the *saliva*, the *tears*, the *perspiration*, the *mucus* secretion and the *pancreatic juice* are all augmented.

Muscle.—Physostigmine produces powerful contractions of the *Stomach, Intestine, Uterus, Ureter, Bladder, Spleen* and *Bronchial Muscle* resembling those elicited by muscarine and pilocarpine. It differs from these, however, in not acting on the inhibitory nerves of the uterus.

The *Intraocular Muscles* also undergo contraction, and their movements under physostigmine have been the subject of a large number of investigations and of a good deal of controversy. The pupil contracts when physostigmine is employed either locally or internally, and this contraction may be lessened by the subsequent application of atropine, but is not altogether removed except by large quantities. On the other hand, the dilatation of the pupil produced by small quantities of atropine may be diminished by physostigmine, but the resulting contraction is much less than that caused by physostogmine applied to the normal eye. The ciliary muscle is acted on in the same way as the iris, so that the eye becomes accommodated for near distance, and atropine induces the same modifications. The effects of physostigmine, then, on the secretory organs, pupil and ciliary muscle are strictly analogous, and are generally attributed to the alkaloid stimulating the terminations of the nerves in these organs. Physostigmine does not contract the pupil after degeneration of the motor oculi nerve (Anderson), which apparently involves its receptor; it is suggested that physostigmine acts on the terminations of the nerves in the iris, while pilocarpine and atropine, which act after degeneration, affect some receptor between

these and the actual contractile substance. The antagonism of physostigmine to atropine is more complete than that of pilocarpine, for a renewal of the contraction can be elicited more easily by the former alkaloid. The intraocular pressure is reduced by the application of physostigmine to the eye and this has generally been attributed to the contraction of the pupil facilitating the escape of the fluid by allowing it freer access to the spaces of Fontana. Another factor may be contraction of the intraocular vessels, which lessens the secretion. (Grönholm.)

Peripheral Action.—It has been discussed whether physostigmine actually stimulates the myoneural junctions, that is, causes impulses to be emitted by them as pilocarpine does, or whether it merely renders them more sensitive to stimuli descending the nerve fibres; the latter seems to be the case in some instances, for it is found that when the chorda tympani nerve is cut physostigmine often fails to cause secretion, though electrical stimulation of the nerve is more efficient than before. In other instances physostigmine appears to act after the impulses from above are excluded, so that here it has the same action as pilocarpine. It is possible that the failure of physostigmine to contract the pupil after degeneration of the postganglionic ciliary branches may be due to the exclusion of the impulses from the centres (Loewi and Mansfeld). The action of physostigmine is complicated by its increasing the amount of adrenaline secreted into the blood. This may act in the same direction as physostigmine, for example, on the motor fibres of the uterus, or may oppose it, for example by inhibiting the movements of the intestine which physostigmine augments; in some conditions the injection of physostigmine may actually arrest peristalsis from this secondary effect.

Some physostigmine is **Excreted** in the urine, but most of that ingested is destroyed in the tissues. It has also been found in the saliva and bile.

The symptoms of poisoning with Calabar bean are identical with those caused by physostigmine, except when an old preparation is used, when some stimulation of the spinal cord may be induced.

Preparations.

Physostigminæ Salicylas, eserine salicylate (U. S. P.), 0.001 G. ($\frac{1}{60}$ gr.).
Physostigminæ Sulphas, eserine sulphate (B. P.), 0.001–0.002 G. $\frac{1}{60}$–$\frac{1}{30}$ gr.
Lamellæ Physostigminæ (B. P.), each containing $\frac{1}{1000}$ gr. of physostigmine sulphate.

The sulphate and salicylate of physostigmine are colorless or faintly yellow crystals, without odor, but possessing a bitter taste. The sulphate is deliquescent in the air and is very soluble in both alcohol and water. The salicylate is not deliquescent, has usually a slight acid reaction, and is soluble in 150 parts of cold, or 30 parts of boiling water. Both salts undergo decomposition when kept in solution and then assume a reddish-brown color; the addition of boric or sulphurous acid to the solution is said to retard this decomposition.

Therapeutic Uses.—In recent years physostigmine has been given in pills or hypodermically ($\frac{1}{60}$ gr.) in cases of atony of the intestine leading to tympanitis and meteorism. But it is chiefly used for its action on the

intraocular muscles and tension. For this purpose a solution of $\frac{1}{3}$–1 per cent. is dropped in the eye, 2–4 drops at a time, or small discs of gelatin impregnated with the alkaloid may be applied to the conjunctiva (B. P.). The pupil begins to contract in five to fifteen minutes, and attains its smallest size in half an hour. It remains contracted twelve to fourteen hours, and according to some observers a difference in the size of the two pupils may be made out for several days. The ciliary muscle contracts along with the iris, and the eye becomes accommodated for short distances. This action on the accommodation passes off in two to four hours, but the sight is often rendered indistinct for some hours longer by alternate contraction and relaxation of the ciliary muscle. The action of physostigmine on the eye differs from that of muscarine, for the former acts more on the pupil, the latter on the ciliary muscle, and the pupil is often contracted by physostigmine while the accommodation is practically unchanged. The intraocular pressure is somewhat increased at first and subsequently sinks. Its action in narrowing the pupil after atropine has been made use of to remove the dilatation produced so frequently in ophthalmic surgery, but homatropine and hyoscine, which produce a shorter mydriasis than atropine, have almost driven it from the field. It antagonizes the dilatation of the pupil after homatropine and cocaine much more successfully than that due to atropine. It has also been used in cases of synechia (attachment of the iris to the lens) alternately with atropine. The alternate contraction and dilatation of the pupil would, it was hoped, break down the attachment, but the condition is now generally treated by operation.

Physostigmine is now chiefly employed to reduce the intraocular pressure in glaucoma.

Guanidine, $CNH(NH_2)_2$, and methylguanidine, $CNHNH_2NHCH_3$, two bases occurring in animals and plants, resemble physostigmine in their effects, causing fibrillary twitching of the muscles, which is opposed by curara and obviously arises from stimulation of the same myoneural receptors as are affected by physostigmine. Vomiting, salivation, bronchial spasm also occur as under physostigmine. On the other hand the central nervous system is more distinctly stimulated, for violent convulsions are induced by guanidine, these arising partly from the brain and partly from the cord. These bases are of special interest as they are regarded as the poisons involved in the idiopathic tetany of children and in the similar convulsive attacks in animals after the removal of the parathyroid gland (Paton); these organs normally have the function of destroying the guanidine formed in the course of metabolism.

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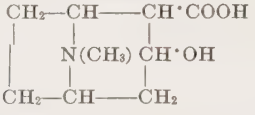
XIV. COCAINE.

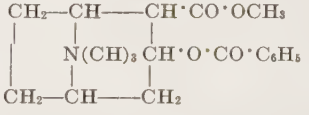
Cocaine is a comparatively recent addition to therapeutics, although the coca plant has been in use in South America for centuries. It is indigenous there, but has been introduced into India, Ceylon and Java. The leaves of the coca grown in Peru and Bolivia contain cocaine along with small quantities of other alkaloids, but the Indian coca and still more the Java leaves contain a smaller proportion of cocaine and a larger amount of the less known alkaloids.

Cocaine, like atropine, is readily decomposed into several constituents. On heating it with water, methyl alcohol is thrown off, leaving *Benzoyl-ecgonine*, which may be further broken up into benzoic acid and *Ecgonine.*

Ecgonine.



Cocaine.



Many artificial cocaines have been formed by substituting other radicals for the methyl or benzoyl in this formula, and several of these have since been found in the cultivated plant, as for example *Cinnamyl-cocaine*, in which cinnamyl occupies the position of benzoyl in the above formula. Various other alkaloids, such as *truxillyl-ecgonine*, and decomposition products are also present; all of these contain the ecgonine molecule in combination with various acids, and cocaine may be formed from all of them by isolating the ecgonine and combining it with benzoic acid and methyl. These alkaloids are present in the plant in very small quantities compared with cocaine and have not been used therapeutically. Another alkaloid which has been found in the Java coca is *Tropacocaine*, which is a combination of benzoic acid and a base ($C_8H_{15}NO$). It will be observed that the formula of tropine resembles very closely that of ecgonine, which is a carboxyl-tropine.

The most important effects of cocaine are those on the central nervous system and on the sensory nerves.

Symptoms.—The symptoms of cocaine poisoning in man vary a good deal in different individuals. In most cases small quantities produce some excitement, pleasurable or disagreeable. The patient is generally restless and more garrulous than in ordinary life, often somewhat anxious and confused. But very often a small dose is followed by a calm, languorous state, somewhat resembling that induced by small quantities of morphine, but differing from it in there being less tendency to sleep. The pulse is accelerated, the respiration is quick and deep,

the pupil generally dilated, and headache and dryness of the throat are complained of. The reflexes may be found somewhat more easily excited than usual and tremors or slight convulsive movements often occur; tonic or clonic convulsions sometimes supervene later, the heart becomes extremely accelerated, the breathing becomes rapid and dyspnœic and may be finally arrested during a convulsion. In most cases the convulsive seizures are entirely absent, however, and fainting and collapse occur, apparently from the rapid absorption of a large dose. The skin is cyanotic and cold, the heart slow and weak; the respiration is very much depressed and death follows from its gradual cessation. Vomiting is occasionally seen at an early stage, but is not by any means common.

In the dog, cat and rabbit the symptoms are invariably those of stimulation of the central nervous system. Soon after the injection the animal shows symptoms of great restlessness and excitement; it seems unable to keep still, the dog at first showing all the signs of affection and excitement which he displays on ordinary occasions on being unchained or taken for a walk, but afterward running continually in a circle and paying but little heed to anything around him. Still later regular convulsions occur, and these are at first clonic, but may afterward become tonic, and then resemble those seen in strychnine poisoning. Even before the convulsions appear the animal seems partially unconscious, and in the intervals between them he lies in an apathetic state, which soon deepens to coma and death from asphyxia.

In the frog a certain amount of stimulation of the central nervous system is often displayed after small doses—increased movement, exaggerated reflex and occasionally convulsions—but these soon pass into depression and eventually total paralysis of the central nervous system, while the peripheral nerves still maintain their functions.

General Action.—Many of these symptoms point to a stimulant action on the **Central Nervous System**, resembling closely that seen in atropine poisoning. Thus the garrulity which is so often produced by cocaine, indicates augmented activity of the cerebrum, and the increased movement in the lower animals distinctly points to an affection of this part of the brain, for the movements are perfectly coördinated, and, in fact, in the early stages resemble exactly those performed by the normal animal in a condition of excitement. Further evidence of the action of cocaine on the cerebrum is offered by its effects on muscular work. The natives of Peru and Bolivia have used it for centuries to increase their endurance of fatigue. The bearers of the Andes, for example, march for hours and days with very little rest or food when they are supplied with coca leaves to chew. The effects of cocaine on the muscular power and on fatigue have been investigated also by means of the ergograph and dynamometer, and all observers are at one in asserting that much more work can be done after cocaine than before it, and that it has a surprising potency in removing fatigue. As regards mental work, its effects are less known, but on the analogy of caffeine it may be supposed to increase the mental

powers also when taken in small quantities. Some travellers in South America relate marvellous tales of its producing feelings of the highest bliss and power, but these have not been confirmed by experience of the action of cocaine in less romantic regions of the globe. Cocaine in small quantities, then, increases the higher functions of the cerebrum, while in somewhat larger doses the stimulant effect spreads to the lower areas and produces a very great increase in movement, accompanied, it would seem, by a depression of the consciousness. At the same time, the coördinating or balancing powers seem affected, so that the animal generally moves in a circle, the symptoms resembling the forced movements often seen in affections of the cerebellum.

The motor areas of the cerebrum have been found to be more easily stimulated by the electric shock when cocaine is injected, though when it is painted on the surface of the brain it lowers the irritability, owing to its being present in too great concentration. Still larger quantities induce convulsions, which are not of spinal origin, but point rather to action on some undetermined part of the hind brain. At an early stage the medulla oblongata is affected, as is shown by the quickened respiration, and the exaggerated reflexes indicate stimulation of the spinal cord, which may be so great after very large doses as to cause convulsions like those produced by strychnine. The action of cocaine on the central nervous system is primarily a descending stimulation, the cerebrum being first affected, then the hind brain and medulla oblongata, and last of all the spinal cord. Perhaps it might be better expressed by saying that after small quantities the chief symptoms arise from the cerebrum, but as the dose is increased those from the lower parts of the central axis tend to become more prominent. After the stimulation there succeeds depression, which follows the stimulation downward, affecting first the cerebrum and then the lower divisions. The two stages are not definitely divided, however, one part of the cerebrum often showing distinct depression, while another is still in a condition of excessive activity. In some cases, especially in man, when a large dose is rapidly absorbed, the stage of excitement may be very short or apparently absent and the whole course of the symptoms then points to medullary depression.

The **Respiration** after cocaine is much accelerated, owing to central stimulation. At first the depth of the movement is not changed, but as the acceleration progresses the air inspired with each breath gradually becomes less. During the convulsions the respiration is irregular or ceases, but it recovers again in the intervals, until after a very violent paroxysm it fails to be reinstated. In other cases the breathing becomes slower and weaker after a time, and eventually stops from paralysis of the centre. Periodic respiration is frequently seen, of the form generally known as Cheyne-Stokes'. (See Morphine, page 250.)

The **Circulation** is altered by cocaine, owing to its action on the heart and on the vessels. The heart is much accelerated in mammals, while in the amphibians this is less often observed. The quickening has been ascribed to paralysis of the inhibitory terminations, but this

seems not to be the case, for stimulation of the vagus slows the heart even late in the poisoning. The heart is accelerated, then, either by direct action on the muscle or by stimulation of the accelerator mechanism. It is often slow before death, but apparently not invariably, and this is probably due to direct action on the muscle. In the frog's heart the inhibitory apparatus is paralyzed, the ganglia being affected in the same way as by curara and other drugs.

The vessels are much contracted in the earlier stages of poisoning, and this, together with the increased rate of the heart, leads to a very considerable rise in the blood-pressure. The constriction of the vessels seems due to stimulation of the vaso-constrictor centre, for it is absent after section of the spinal cord. The blood-pressure subsequently falls, from peripheral action, if Anrep's assertion is correct that stimulation of the splanchnic then produces no further rise of pressure. When applied to mucous membranes, cocaine constricts the vessels from direct action on their walls, but there is no reason to believe that these are affected in general poisoning, since the necessary concentration would prove fatal from action on the heart and respiratory centre.

The effects on the peripheral **Nerves and Muscles** are disputed, for Mosso states that small quantities increase the strength of the muscular contractions on electrical stimulation both in man and animals, while others have failed to obtain any such effect.

The movements of the **Intestine** are augmented after cocaine in the intact animal and also when the organ is excised and suspended in Ringer's solution. This seems due to direct action on the muscles and larger amounts lessen the movements and finally paralyze them.

The **Urine** is sometimes said to be increased by cocaine, while in other instances its injection has been followed by total anuria lasting for several hours. This suggests that the action is not a direct one on the kidney, but is caused merely through the changes in the calibre of the vessels.

The other **Secretions** seem rather decreased than augmented, but no very marked effects are produced on them.

The **Temperature** generally rises in cases of poisoning, sometimes as much as 3–5° C., from increased heat formation caused by cerebral action. Langlois and Richet observed that the higher the temperature of the animal the more easily were convulsions produced by cocaine and the more severe their type.

It used to be supposed that cocaine retarded the **Tissue Change** and that less food was required when it was supplied. This was based on the statement of the endurance of the natives of South America when they were allowed to chew coca leaves, and on the discovery that the leaves also allay hunger to some degree. But the increase in the working power is due to the effects on the central nervous system, while the craving for food is probably lessened owing to the cocaine inducing numbness of the sensory nerves of the stomach through its local action. Careful investigation has failed to reveal any significant action on the metabolism of animals except when large quantities were given over several days, when the utilization of the protein and fats was found to be impaired.

A curious effect of cocaine, noted by Ehrlich in mice, is a widespread destruction of the hepatic cells, which become infiltrated with fat and often undergo necrosis.

Some cocaine is **Excreted** by the kidney in the dog, and in the rabbit nearly the whole of that ingested may reappear in the urine, the tissues seeming to have little or no power of destroying it in this animal. It is unknown whether it is excreted in man, who is much more susceptible to its action than these animals.

Tolerance appears to be attained in man when cocaine is used habitually, for in some cases enormous doses are taken. In animals repeated injection leads to a cumulation of cocaine in the tissues and hence the animal instead of becoming more tolerant becomes more susceptible to each new injection. As the concentration in the body increases, the amount in the urine rises (Grode).

Local Action.—Cocaine applied locally in most parts of the body produces a loss of sensation through its paralyzing the **Terminations of the Sensory Nerves**, particularly those conveying impressions of pain and touch. The exact researches of Kiesow show that at first heat and cold are recognized as readily as in the unaffected parts of the body. Cocaine applied to the tongue removes the taste of bitter substances, while sweet and acid fluids lose their taste only partially, and salt is recognized as easily as usual.[1] A solution applied to the nasal mucous membrane paralyzes the sense of smell entirely.

The anæsthesia or insensibility to pain and touch may be induced in any of the mucous membranes that can be reached by cocaine in sufficient concentration—pharynx, larynx, œsophagus, stomach, nose, eye, urethra, bladder, vagina, and rectum. Applied to the unbroken skin its effects are less marked, as it penetrates but slowly through the horny epidermis; but when the epidermis is removed by abrasions or by skin disease, the cutaneous organs of sensation are acted on in the same way as those of the mucous membranes. The deeper sensory terminations can also be acted on by hypodermic injection, which causes a feeling of numbness and the relief of pain in the part. Hypodermic injection reaches not only the nerve terminations of the subcutaneous tissues, but also the finer nerve bundles, and these too are rendered insensible as far as the solution extends to them. The part may therefore be cut into or be subjected to other surgical treatment without pain, as long as the knife does not pass beyond the area to which the drug has penetrated, and numbers of grave surgical operations have been performed under the local anæsthesia produced by cocaine.

Injected into the neighborhood of a nerve trunk, cocaine penetrates into the fibres and induces anæsthesia of the organs supplied by the nerve, and injected into the spinal canal it causes anæsthesia over large areas

[1] A curious contrast is presented in this respect by gymnemic acid, which is obtained from the Gymnema silvestre, and which removes the sensation of sweetness, while "bitter" is less affected and "acid" and "salt" are recognized as readily as usual. Gymnemic acid does not affect any other sense organs, as far as is known, and is, in fact, devoid of interest except as regards its effect on taste.

of the body, sometimes over almost the whole body, from its acting on the posterior roots of the cord. It must be noted that the anæsthesia is only produced by the local application of the drug. The internal administration only leads to a partial loss of sensation in the throat and stomach, and no anæsthesia is induced by its action after it reaches the bloodvessels. The reason for this evidently is that in order to paralyze the sensory fibres and terminations a considerable amount of the drug is required, but much less is necessary to paralyze the central nervous system. Even in the frog the sensory terminations are not fully paralyzed until all symptoms of reflex excitability have disappeared and total paralysis has supervened.

Cocaine applied to a nerve trunk proves to have a distinct selective action, for the sensory fibres fail to conduct sensory impressions, while motor impulses pass through the fibres without difficulty. Similarly, when it is injected into the spinal canal, complete loss of sensation in the lower part of the body follows, but the movements are almost unimpaired. This selection is only relative, for larger quantities paralyze the motor nerve fibres also; no explanation has been given for this difference in the reaction of the two sets of fibres. When cocaine is applied to the vagus nerve, it paralyzes the cardiac inhibitory fibres, while the afferent impulses to the respiratory centre are more resistant.

When cocaine is applied locally to a mucous membrane it produces, besides a loss of sensation, a feeling of constriction and a distinct pallor and contraction of the vessels, which point to a local action on the vessel walls.

The anæsthesia produced by cocaine is comparatively short, but varies with the strength of the solution applied and with the vascularity of the part; as soon as the cocaine is absorbed, the local action disappears and sensation returns.

It has recently been observed that the prolonged muscular cramp seen in various nervous diseases and notably in tetanus, disappears when cocaine is injected into the muscles; this has been attributed to its paralyzing the sensory terminations in the muscle and thus arresting the proprioceptive stimuli which, passing to the spinal cord from the muscle, maintain its excessive activity (Magnus). But if, as is asserted, cocaine also arrests the muscular contractions induced by nicotine, guanidine, etc., even after degeneration of the nerves, this explanation is insufficient and the action must be an antagonistic one on the receptors affected by these (Frank).

Cocaine is applied to the **Eye** more frequently than to any other part. It produces local anæsthesia here, along with contraction of the conjunctival vessels, and this is followed by dilatation of the pupil and often by partial loss of the power of accommodation. The dilatation of the pupil is much less than that produced by atropine, and differs from it in several respects. Thus, the light-reflex is preserved, the pupil contracting in bright light and dilating further in the dark; a number of drugs which have little or no effect after atropine, contract the cocainized pupil (pilocarpine, muscarine, physostigmine), while

atropine dilates it still further, and cocaine produces some dilatation after the full atropine action has been elicited. The motor oculi nerve is not involved in the action of cocaine, unless very large quantities are applied, when its terminations may be depressed in the same way as by atropine (Schultz). It is often stated that cocaine dilates the pupil by stimulating the ends of the nerves in the fibres of the dilator muscle (Fig. 26) in the same way as adrenaline. But this is not established by any satisfactory evidence, and cocaine differs from adrenaline in not affecting the sympathetic fibers in any other organs. Another explanation of the dilatation has been suggested, namely that cocaine acts directly on the muscle fibres of the iris and weakens the circular muscle (Kuroda). And this is supported by the observation that all other forms of unstriated muscle are affected in the same way

The effect on the intraocular pressure seems to vary; it is sometimes reduced, from constriction of the vessels perhaps, while some cases are recorded in which the use of cocaine was followed by an acute attack of glaucoma, which is ascribed to the cocaine relaxing the iris and thus impairing the escape of fluid from the eye in the way which is more familiar under atropine.

General Protoplasmic Action.—The effects of cocaine on the nerve fibres and sensory terminations is so striking that its toxic action on other forms of living matter is liable to be forgotten. The anæsthetic action is, however, merely an instance of its general toxicity, for if brought in contact with other forms of living matter in the concentration used in anæsthetising nerve ends, it is poisonous to all the structures which have been examined. Even concentrations too low to act on the peripheral nerves act on the nerve cells and paralyze them, so that it is impossible to induce a general loss of sensation by cocaine injected into the circulation, and local anæsthesia can be induced only by applying relatively strong concentrations and confining their action to definite areas. The ciliated epithelial cells, leucocytes and spermatozoa become motionless, the cortical nerve cells lose their excitability, and many of the invertebrates are killed by even a short exposure to cocaine. The movements of protoplasm in plants are also retarded or entirely suppressed by this poison, and the process of putrefaction is delayed considerably. In some cases, notably in the higher invertebrates, the final depression is preceded by a stage of increased movements, and vertebrate muscle cells, whether striated or unstriated, are first aroused to greater activity and then depressed and paralyzed (Kuroda). In some other instances, however, cocaine induces only depression and paralysis.

Other examples of this destructive action are also seen in the therapeutic use of cocaine, for the cornea is often rendered cloudy from its application, and its subcutaneous injection is sometimes followed by necrosis. Victims of the cocaine habit often show numerous scars on the arms and legs from this local gangrene, although this is probably often due to unsterilized syringes rather than to the solution.

An interesting analogy has been drawn by Gros between cocaine and the general narcotics of the alcohol-chloroform series, which also have some action

on nerve fibres and terminations when they are applied directly. They act in lower dilution on the central nerve cells, however, and do not affect the sensory fibres more than the motor, while the concentration of cocaine which affects the nerve cell is less distant from that which acts on the peripheral fibre and it acts more strongly on the sensory than the motor nerves.

Most of the other natural alkaloids resemble cocaine in many points of their action, as far as they have been investigated, but some of the artificial compounds present divergences from the general type. Thus a number of them do not produce anæsthesia, and some of them depart entirely from the typical cocaine action.

Truxillyl-ecgonine is often said to be a cardiac poison, but its action on the heart seems to resemble in general that of cocaine. It has, however, a more intense action on muscular tissue, which it, like caffeine, throws into rigor mortis. Its anæsthetic power is very small. Some authorities regard the muscular action of caffeine as an important factor in its preventing fatigue, and the presence of truxilline in the coca leaves might be used to explain the similar effects induced by these, but the quantity is probably too small to have any noticeable action.

Benzoylecgonine is a comparatively weak body, which produces symptoms resembling caffeine—increased reflex excitability, muscular stiffness, and rigor —and *ecgonine* is still less active, but elicits similar effects in frogs.

Cocaine Habit.—Since the introduction of cocaine into general therapeutic use, numerous cases of the formation of a habit similar to that of opium or morphine, have been recorded. Some of these have been due to the attempt to substitute cocaine for morphine in the treatment of chronic morphinism, the treatment often resulting in the development of an irresistible craving for both alkaloids. The symptoms of cocainism generally begin with digestive disorders, loss of appetite, salivation and emaciation, but the more important changes occur in the central nervous system, which apparently undergoes degeneration similar to that seen in chronic morphine poisoning. Sleeplessness, tremors and occasionally convulsions, hallucinations, insanity and delirium have been noted after long abuse, along with indefinite disturbances of sensation and motion. The treatment of these cases is the withdrawal of the drug, and this can generally be done without the production of any special symptoms, though it is sometimes followed by great depression. This treatment is much facilitated by sending the patient to a special resort, and, in fact, is almost hopeless without his isolation.

Acute Cocaine Poisoning is treated purely symptomatically. Amyl-nitrite has been advised when the blood-pressure seems much elevated, while for the convulsive attacks small quantities of chloroform or ether may be necessary. Of course, the stomach ought to be evacuated first of all if the drug has been taken by the mouth.

Preparations.

Cocaina (U. S. P., B. P.), an alkaloid ($C_{17}H_{21}NO_4$) obtained from the leaves of Erythroxylon coca and its varieties, forming colorless crystals with a bitter taste followed by numbness; insoluble in water, soluble in alcohol.

Cocainæ Hydrochloridum (U. S. P., B. P.) ($C_{17}H_{21}NO_4HCl$), colorless crystals, very soluble in water and alcohol; watery solutions cannot be boiled as the alkaloid tends to decompose.

Lamellæ Cocainæ (B. P.); each contains $\frac{1}{50}$ gr. of the hydrochloride.

Ointments and other preparations containing cocaine should be used only by the physician, as they have repeatedly given rise to the cocaine habit when supplied to patients. For this reason lozenges containing cocaine should not be prescribed.

Substitutes for Cocaine.

In the early days of local anæsthesia with cocaine, a number of fatalities occurred from its use and prompted the search for a less dangerous substitute. About one hundred of these have been introduced but only a few have been widely used; in most of these a benzoyl group is contained as in cocaine and its presence is generally essential to the anæsthetic action. This is inherent in a very large number of chemical substances, but in most instances the anæsthesia is preceded by irritation and pain; even cocaine is not devoid of deleterious local action. In comparing the advantages and drawbacks of the various local anæsthetics, the points to be examined are the general toxicity on absorption, the power of inducing local anæsthesia, and the extent to which the paralysis of the nerve ends is preceded by irritation and is attended by injury to other cells in the neighborhood.

The first important substitute for cocaine was **Beta-Eucaine** or **Benzamine** ($C_{15}H_{21}NO_2$) which is an artificial base analogous to cocaine, and like cocaine first stimulates and then paralyzes the central nervous system when injected into animals in large doses; the pulse is slowed from direct action on the cardiac muscle, and the blood-pressure falls. Eucaine is only about half as poisonous as cocaine. As a local anæsthetic, it is almost as efficient as cocaine but often induces irritation. It does not constrict the vessels nor dilate the pupil; its effects on the intraocular pressure are not yet satisfactorily determined.

Benzaminæ Lactas (B. P.), Beta-eucaine lactate ($C_{15}H_{21}NO_2C_3H_6O_3$), a white crystalline powder with a bitter taste followed by numbness, soluble in 5 parts of water.

Betaeucainæ Hydrochloridum (U. S. P.) ($C_{15}H_{21}O_2NHCl$), a white crystalline powder, soluble in 30 parts of water.

Novocaine or **Procaine** ($NH_2—C_6H_4—CO_2C_2H_4N(C_2H_5)_2$) is about one-third as poisonous as cocaine, and applied locally acts only on the nerves without involving the other tissues and thus produces no irritation or hyperæmia; it does not constrict the vessels nor dilate the pupil. Its anæsthetic action is less powerful and less lasting than that of cocaine, but is sufficient for most purposes when the absorption is delayed by the addition of adrenaline.

Novocaine or Procaine Hydrochloride (unofficial) a colorless odorless crystalline substance, causes numbness of the tongue when placed on it, and is soluble in less than its own weight of water.

Some simpler aromatic substances have been advocated recently, such as **Benzyl Alcohol** ($C_6H_5CH_2OH$) by Macht, and **Phenethylol**

($C_6H_5CH_2CH_2OH$) as possessing good anæsthetic properties with a negligible toxicity, and may prove successful rivals to the bases hitherto used.

Tropacocaine, an alkaloid found in Java coca leaves, is the benzoic ester of a base, pseudotropine. It is about half as poisonous as cocaine when absorbed. Applied locally it equals cocaine in anæsthetic power, but its effects are more transient and it is more liable to cause irritation according to some observers. It has not been employed so widely as the others. Applied to the eye it does not dilate the pupil.

Stovaine, $C_{14}H_{21}O_2N$,HCl, an artificial alkaloid recently introduced, is less poisonous than cocaine, but has occasionally caused alarming symptoms of collapse. Its local anæsthetic action is comparable to that of cocaine, but is attended by some signs of irritation.

Alypine, $C_{16}H_{26}O_2N_2$,HCl, is closely related to stovaine in chemical structure. It is equally poisonous with cocaine and though it also equals it in its local anæsthetic action, this is attended by marked irritant congestion and even sloughing. Alypine has therefore no claims to use in therapeutics.

Orthoform and **Orthoform-neu**, ($C_6H_3.NH_2.HO.COOCH_3$) are methyl esters of amido-oxybenzoic acid, and are almost insoluble in water. They have been used as dusting powders and in ointment to allay pain in ulcers and burns; but in a number of instances they have given rise to severe irritation and sloughing, and they must be used with the greatest care, if at all. **Anæsthesine** ($C_6H_4.NH_2.COOC_2H_5$) and **Propæsine** ($C_6H_4.NH_2.COOC_3H_7$), which do not contain the hydroxyl group of orthoform, are less liable to cause this local irritation and may be used as applications to wounded surfaces and to mucous membranes to relieve pain and irritation; their action is more prolonged than that of the soluble preparations; on the other hand they cannot be applied in solution, and are not available to anæsthetize the unbroken skin. Dose 0.3–0.5 G. (5–8 gr.) used as dusting powder or in ointment (1–10 per cent.).

A number of investigations have been made of the relative anæsthetic power, toxicity and irritant action of the local anæsthetics, and while some divergences occur in the results, there is practically unanimity that when the drugs are applied by injection, novocaine and tropacocaine are efficient substitutes for cocaine, while eucaine is less satisfactory (Sollmann). On the other hand when a mucous membrane is to be anæsthetized by painting a solution of the drug on it, novocaine is of little value and eucaine alone approaches cocaine in efficacy. Novocaine is the least toxic of those in common use and does not injure the tissues, so that its use as a substitute for cocaine is extending rapidly. Cocaine and eucaine are now being employed only for surface anæsthesia. Gros states that all the alkaloidal anæsthetics have greater action when applied as bases and suggests that they should be applied along with sodium bicarbonate sufficient to free them from the salts.

Another local anæsthetic which has been used largely is quinine hydrochloride. Cold may also cause insensibility of the skin and superficial tissues (p. 74), and the anæmia of a limb caused by an Esmarch's bandage has also been employed.

Therapeutic Uses of the Local Anæsthetics.

The therapeutic uses of cocaine and its allies are almost all dependent on their anæsthetic action. Cocaine has been suggested as a brain stimulant in various conditions of mental depression, and also in asthma and hay fever, but its use is dangerous from the tendency to the habit being formed. A wine containing coca extract used in domestic medicine as a "general tonic," has repeatedly given rise to it.

Only the general principles of local anæsthesia can be discussed here, and of these one is that the dangers of cocaine poisoning are sufficiently great and so unforeseen that less poisonous anæsthetics should be substituted where possible. Where it is necessary to use cocaine, the solution should be as dilute as possible and should contain five drops of adrenaline solution in order to constrict the vessels and thus retard the absorption into the general tissues; the addition of adrenaline also intensifies the action of all the local anæsthetics by preventing their absorption and thus maintaining the concentration in the field of operation. Cocaine is still unrivalled in its power of penetrating the mucous membranes, and this is now its chief field of usefulness; the hydrochloride is dissolved in 0.8 per cent. sodium chloride solution, or better in Ringer's solution, in order to avoid the effects of water on the tissues. In ophthalmic surgery it is used very largely both during operation and to alleviate pain, and occasionally to constrict the vessels of the iris in inflammatory conditions. For complete anæsthesia a 4 per cent. solution may be employed, while to allay pain one of 1–2 per cent. is all that is necessary. The anæsthesia is of short duration, generally setting in after five to seven minutes and passing off twenty to thirty minutes after the application of the drug. Eucaine 2–5 per cent is not so reliable. Occasionally cocaine, especially in strong solution, produces a certain amount of opacity of the cornea, and wounds heal less readily and irritant antiseptics are more dangerous with cocaine than without it. This arises from the general toxic action of cocaine on living matter, which tends to lessen the resistance of the tissues with which it comes in contact. The usual explanation given that cocaine paralyzes sensation in the cornea, and thus prevents the reflex winking which removes foreign bodies from the surface and keeps the eye moist, is obviously insufficient, as the anæsthesia is of but short duration. The dilatation of the pupil produced by cocaine is much less complete than that under atropine, and can only be taken advantage of in diagnosis by using a very dim light, as the pupil contracts in bright light almost to its normal size. On the other hand cocaine is less injurious in glaucoma and the dilatation can be removed at once by the instillation of a few drops of physostigmine.

In the nose, throat and larynx, cocaine is used in a solution of 4 per cent., either painted or sprayed on the surface or soaked in lint with which the nose is packed; anæsthesia is obtained with greater difficulty than in the eye, and a considerable number of fatalities have occurred from its use in nose and throat work; this is mainly due to the

use of strong solutions such as 10 or even 20 per cent. to saturate lint. Where possible, one of the substitutes should be given by submucous injection. Similarly cocaine has been superseded in dentistry by the injection of novocaine into the gums. Eucaine has also been painted or sprayed in 5–10 per cent. solution but is less efficacious than cocaine. In the urethra, rectum and vagina, cocaine (1–2 per cent.) is used either as an anæsthetic or to relieve pain temporarily.

For many years after its introduction as a local anesthetic in 1884, the use of cocaine was practically limited to minor operations in the nose and throat and to ophthalmic surgery, few general surgeons venturing on its application except in quite minor operations which required only a small incision and no manipulation; for this purpose cocaine is still injected into the site of operation in general practice in which it is found more convenient than the local anæsthesia induced by cold (see p. 74); but its place is being taken by less poisonous members of the group, which are equally efficacious when injected under the skin and are practically devoid of danger of general poisoning. Within the last few years, however, the use of local anæsthesia has undergone a wide extension, so that almost all the major surgical operations have been performed under it, and it has now become a rival of ether and chloroform. Occasionally partial local anæsthesia is combined with the administration of small quantities of chloroform or ether, which are insufficient to produce complete unconsciousness, but cause a numbing of the sensation, which, together with the local action, permits of a painless operation. At first strong solutions were injected to prepare the way for the knife, each step forward in the operation being preceded by an injection to induce anæsthesia of the layer of tissue to be incised. But this method, which has been advocated by Reclus, is now scarcely used except for minor operations in which a single injection is sufficient. (Cocaine, eucaine, or novocaine in 1 per cent. solution).

A more satisfactory method of local anesthesia for operative purposes has been introduced by Schleich under the name of *infiltration anæsthesia*. A large quantity, generally about 100 c.c. of a solution containing 0.1 per cent. of cocaine, or 0.25 per cent. of eucaine or novocaine, and 0.8 per cent. of sodium chloride is allowed to permeate the tissues through a fine hypodermic needle. Only very slight pressure is required and the whole of the surrounding structures become swollen and œdematous and can be cut into without pain. Much of the fluid escapes through the incisions and no symptoms of poisoning arise.

Another method (*regional anæsthesia*) is the injection of cocaine, or one of its substitutes, in 1 per cent. solution into the immediate neighborhood of the nerve supplying the part to be operated on. Complete local anæsthesia is obtained, and shock is less liable to occur than when general anæsthesia is induced (Crile). This method has been used extensively in operations on the foot and hand, for which it is admirably suited; it can also be adapted to other parts of the body. The local action in both infiltration and regional anæsthesia may be augmented and the danger of general poisoning lessened by retarding the circulation in the part

to be operated on. This may be done by applying an Esmarch bandage above it when a limb is involved, or by the application of cold by means of ethyl chloride; but the best results are obtained by using a 1 per mille solution of adrenaline along with the anaesthetic.

Another method of inducing anæsthesia in a limb is by means of *venous* injection. The limb is emptied of blood by elevation and bandaging and a tourniquet is applied above the point where the injection is to be made; the anæsthetic is now injected under some pressure into a superficial vein peripheral to the tourniquet and quickly penetrates by anastomosis throughout the veins of the limb paralyzing sensation wherever it reaches. After the operation the tourniquet is slowly loosened and the anæsthesia disappears with the anæmia. The same strength of solution is used as for infiltration anæsthesia, and the quantity is too small to have any effect when it reaches the general tissues. Intra-arterial injection has also been employed in the same way in bloodless limbs.

After it was found that the nerve impulses from the periphery to the central nervous system could be blocked by the injection of cocaine into the peripheral nerves, the next step was to obstruct them higher in their course by applying it to the spinal roots (*subarachnoid* or *intraspinal anæsthesia*. The first to attempt this was Corning of New York, but the development of the procedure is due to Bier and Tuffier. A long, hollow needle was passed into the spinal canal between the laminæ of the lumbar vertebræ and 1 c.c. of a 2 per cent. solution of cocaine hydrochloride was injected after the withdrawal of an equivalent amount of cerebrospinal fluid. The actual amount of cocaine injected was thus 0.02 G. ($\frac{1}{3}$ gr.). Under cocaine accidents were so numerous that the method was abandoned by conservative surgeons and though it received a new lease when novocaine was substituted for cocaine, it is not very widely used at present. Within a few minutes numbness begins, generally in the feet at first, but sometimes in the lower part of the trunk; it spreads upwards rapidly until sensibility to pain is lost everywhere below the diaphragm and sometimes in the thorax; in some cases even the head has been found anæsthetized. The sensations induced by warmth and cold are less quickly affected, touch is preserved to some extent and the limbs can be moved readily, though the movements are carried out more slowly than usual; the consciousness is unimpaired. This condition lasts from half an hour to an hour and then sensation returns gradually. In the beginning of the action some muscular twitching is often seen, and the muscles are never relaxed as they are under chloroform or ether. Vomiting occurs in a certain proportion of cases either during or after the operation, and persistent headache is often present. A more dangerous effect is the onset of collapse with very low blood-pressure and all the symptoms of cerebral anæmia. This not infrequently fatal accident is attributed to the anæsthetic paralyzing the vasomotor roots of the splanchnic nerves within the spinal canal (Smith and Porter). The anæsthesia from the intraspinal injection arises from action on the posterior nerve roots and not on the

cord itself. The cerebrospinal fluid has been found to contain a large number of polynuclear leucocytes after the injection and resumes its normal limpid character only after several days. This method of anæsthesia has been used in a large number of operations, some of them of the gravest nature; it has also been substituted for general anæsthesia in labor.

Of these methods, Schleich's infiltration has been most widely adopted and is admirably suited for minor operations. It is the safest method available for most of these, for the amount of anæsthetic injected is not sufficient to induce poisonous symptoms, and much of this escapes by the incision. It requires some experience to induce complete insensibility to pain by this method and the operation has to be interrupted at intervals to permit of further injections. Some headache and nausea are occasional sequelæ. When general anæsthesia is contra-indicated, infiltration may be adopted in major operations, while on the other hand it is often contraindicated in minor operations where there is any possibility of complications, or where the anxiety and nervousness of the patient are likely to interfere with the proceedings. Subarachnoid or intraspinal cocainization has been enthusiastically praised by some of its sponsors, but is generally regarded as a hazardous method. Numerous fatalities have resulted from it, and headache and nausea very often persist for many hours after the operation. It is less in use now than a few years ago and is only to be recommended when special circumstances contraindicate the general anæsthetics, and operation is imperative.

The insoluble members of the group, anæsthesine and propæsine are advised as dusting powders or in ointment (1–10 per cent.) in irritating skin diseases and for painful conditions of the mucous membranes of the eye, nose, throat, etc. They are also used in gastritis and gastric ulcer in doses of 0.25–0.5 G. (4–8 grs.). Orthoform tends to cause irritation and even sloughing in some cases when used for these purposes.

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XV. ADRENALINE.

The suprarenal glands of all vertebrates have been shown to contain a body which possesses a powerful action on the organism, and which the glands normally secrete into the bloodvessels. The active principle was first isolated by Abel and named *epinephrine,* but is more widely known under the trade names of *adrenaline, suprarenine,* etc. It has also been found by Abel in the external neck glands of a tropical toad. It is a feebly basic derivative of benzene, corresponding to the formula $C_6H_3(OH)_2—CHOH—CH_2—NHCH_3$. Adrenaline has been formed synthetically, and a number of other amine compounds similar to it in structure have proved to resemble it also in action in many features; other amines less closely related chemically tend to depart further from the typical adrenaline action (Barger and Dale). Adrenaline is lævorotary to polarized light; the dextrorotary isomer has only about one-twelfth of the activity of the natural substance (cf. Atropine and Hyoscine).

The characteristic action of adrenaline is best elicited by its injection into a vein, when it stimulates the myoneural junctions of the postganglionic fibres of the sympathetic nerves. The effects of adrenaline are thus for the most part identical with those of stimulation of the sympathetic nerves and the group of amines of which it is the best known member have therefore been termed the sympatho-mimetic amines. The symptoms show certain analogies with those induced by nicotine, but the latter affects a wider area from its involving the parasympathetic autonomic nerves as well as those of the true sympathetic. And the point at which nicotine acts is the ganglion cell, while adrenaline involves the other end of the peripheral neuron. It should be added that some of the sympathetic terminations are not involved in the action of adrenaline; the secretory fibres in the sweat glands are not affected for example, although they are of sympathetic origin.

Circulation.—On the intravenous injection of adrenaline a very marked rise in the arterial blood-pressure occurs accompanied at first by acceleration, then by slowing, and later again by acceleration of the heart. This rise in blood-pressure is for the most part due to constriction of the vessels of the abdominal cavity, but an increase in the efficiency of the heart often plays a part, though a subordinate one. The sudden increase in pressure occurs after destruction of the vasomotor centre and cord, or after section of the splanchnic nerves and paralysis of the ganglia on the vaso-constrictor nerves, so that it is obviously due to direct action on the muscle of the vessel walls, or on the terminations of the nerves in them. The greatest constriction is seen in the vessels

of the splanchnic area, but most of the other vessels are also involved in lesser degree. Thus the limb vessels are narrowed less than those of the intestine, and the pulmonary and cranial arterioles are so slightly constricted that there has been some difficulty in proving that they are involved in the general action; most observers now hold that there is narrowing in these regions also. The effect on the coronary artery of the heart has also been the subject of dispute, most investigators finding that it is dilated by adrenaline; but though this is often the prevailing effect, very small concentrations of adrenaline cause distinct contraction of the coronary artery and slow the passage of blood through the heart (Brodie and Cullis). Even in organs in which the vessels are more obviously constricted, the degree varies considerably, apparently according to the amount of control normally exercised by the constrictor nerves; thus the vessels of the uterus are more contracted than those of the bladder, and these again more than those of the striated muscles, which may even be dilated from the high blood-pressure arising from the constriction of the splanchnic vessels. The smaller veins are constricted as well as the arterioles, and the constriction of the hepatic venules is more marked than that of the portal branches so that the blood accumulates in the liver which becomes greatly swollen. This leads to a large escape of plasma from the blood and blood-counts therefore show an unusually high content of red cells (Lamson).

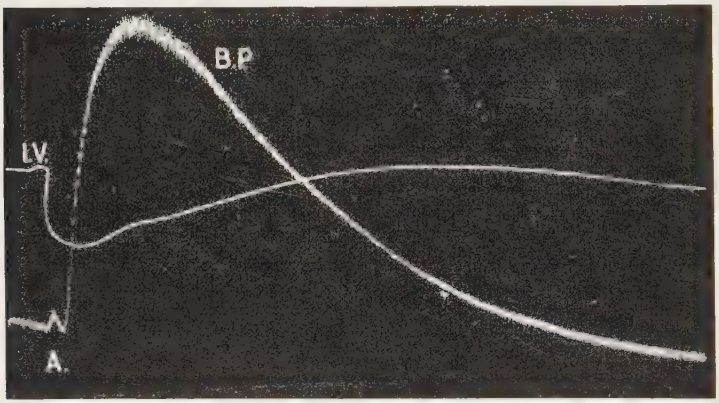
After moderate quantities of adrenaline the blood-pressure falls again after about five minutes, and not infrequently descends below the normal level. And in some instances when adrenaline is injected into an animal whose blood-pressure is very high, a fall of pressure occurs instead of the usual rise. Further, when the sympathetic myoneural junctions in the vessels have been paralyzed by ergotoxine, adrenaline causes a distinct fall in the blood-pressure instead of the usual rise. When very minute quantities of adrenaline are injected in the unpoisoned cat or dog, a fall in the blood-pressure generally occurs, while a larger quantity induces vasoconstriction with the typical rise in pressure. This reversal of the adrenaline reaction has generally been explained by the theory that it stimulates not only the terminations of the vasoconstrictor nerves but also those of the vasodilators, and that the former usually prevail, but under certain conditions may be exhausted more quickly or may be ineffective and the vasodilator stimulation then prevails. Another view has been suggested by Dale and Richards, that adrenaline causes dilation of the capillaries, which is generally overshadowed by the constriction of the arterioles; but when this fails to occur, or is of short duration, the capillary change comes into play and the blood-pressure falls accordingly.

The acceleration of the heart under adrenaline is due to stimulation of the terminations of the accelerator nerves in the heart-muscle, and is therefore accompanied by a stronger contraction and more complete evacuation of the chambers; if the dose injected be large the accelerator action is too great to admit of complete relaxation during the diastole, and the output of the heart may be smaller, and a drop in the blood-

pressure is observed. This accelerated beat is the characteristic feature of the adrenaline action, but it often gives place to the slow, full beat characteristic of inhibitory activity. This second phase of slowing of the heart beat is not observed if the vagi are divided or if atropine is given before adrenaline, so that it obviously arises from excitation of the vagus centre; this is not mainly a direct adrenaline action but is largely a secondary result of the high blood-pressure, which induces congestion of the brain and arouses the vagus centre to activity. After a short time, the blood-pressure beginning to fall, or, the vagus centre becoming exhausted, the accelerator stimulation again gains the upper hand and the pulse is again much accelerated.

The effect of adrenaline on the mammalian heart is thus in small dose to accelerate and strengthen it; in large amounts the acceleration may be excessive and impair its efficiency, or the acceleration may be

Fig. 33



Blood-pressure (*B.P.*) and bowel volume (*I.V.*) of cat. At *A* injection of adrenaline. The blood-pressure rises and bowel volume diminishes, indicating constriction of the mesenteric vessels. As these relax again the blood-pressure falls. The vagi had been divided previously, so that there is no secondary slowing of the heart.

temporarily replaced by inhibition which also reduces the output. Adrenaline increases the irritability of the heart and thus predisposes it to pass into fibrillary contractions. The frog's heart is less easily affected than that of the mammals, but similar changes have been observed.

The action on the heart may be demonstrated by perfusing very dilute solutions of adrenaline through the vessels of the excised heart, and the same method is used in investigating its action on the vessels of other organs. In the excised heart the accelerator and augmentor action alone is visible, the stage of slowing being absent. The contraction of the vessels in such organs as the kidney is shown by the diminished outflow from the veins when adrenaline is added to the perfusing fluid; and different organs respond in different degrees, little retardation of the flow occurring in the lungs, brain and heart compared with that in the intestines, limbs, and kidney. A similar con-

striction of the vessels may be observed when a solution of adrenaline is applied to a mucous membrane, for the part becomes pale and anæmic from the constriction of the vessels; this is well seen when the drug is applied to the congested conjunctiva or to the mesentery. Painted on the unbroken skin adrenaline has no effect, as it fails to penetrate it, but denuded surfaces become blanched, and hæmorrhage ceases from small vessels.

When it is injected hypodermically, the skin and subcutaneous tissues around the point of injection become pale and anæmic and may be cut into without bleeding, and when it is applied to a bleeding surface, the hæmorrhage is arrested unless some large artery has been opened. But even the direct application of adrenaline to a lesion of the lung or brain has little effect in stopping the bleeding, the vessels in these organs not being constricted by adrenaline to the same extent as those of other organs.

The **Respiration** sometimes becomes irregular during the period of high blood-pressure, and periods of strong and rapid breathing may alternate with apnea; this is probably a result of the high blood-pressure and not of any direct action on the centre.

Fig. 34

Tracing of the movements of intestine (*I*) and of the uterus (*U*) of a rabbit under adrenaline injected at the point marked with an arrow. The intestine relaxes, while the uterus contracts powerfully.

Stomach and Intestine.—The intravenous injection of adrenaline is followed by immediate cessation of the movements of the stomach and intestine which become relaxed to their full extent. This is in accordance with their innervation, for the splanchnic fibres are the inhibitory nerves of those organs and their stimulation also arrests peristalsis and causes relaxation (Fig. 34). But certain specialized parts of the bowel wall receive motor fibres from the sympathetic—the pyloric,

ileo-colic and internal anal sphincters and the muscularis mucosa—and these are thrown into contraction by adrenaline. The movements of the gall-bladder are inhibited and those of the gall-duct are increased by sympathetic stimulation and also by adrenaline.

The reaction of the **Bladder** to adrenaline differs in different species of animals according to the nature of the dominant impulses of the lumbar sympathetic nerves.

Uterus.—The reaction of the uterus to adrenaline differs in different animals and even in the same animal at different periods. In the non-pregnant cat, adrenaline generally causes inhibition of the movements and relaxation, while in the pregnant cat its injection is followed by powerful contractions; in the rabbit adrenaline almost always causes contraction whether the animal is gravid or not, while in the dog the uterus first contracts and then passes into a position of relaxation and inhibition. In each case the action of adrenaline is identical with that of stimulation of the hypogastric nerves which carry both motor and inhibitory fibres to the uterus; the relative power of the two sets of fibres varies in different animals and in different conditions in the same way as the action of adrenaline (Fig. 34).

The Eye.—The intravenous injection of adrenaline is followed by dilatation of the pupil, the eyelids are widely opened, the eyeball is protruded, and the nictitating membrane withdrawn; the action corresponds exactly to the effects of stimulation of the cervical sympathetic fibres; it occurs when these have been cut, and is even intensified when they have been allowed to degenerate. Applied locally to the eye, it constricts the vessels of the conjunctiva and often dilates the pupil and reduces the intra-ocular tension for a short time.

Bronchial Muscle.—Adrenaline injected intravenously dilates the bronchi widely, an effect which is especially noticeable when they have been previously constricted by pilocarpine or physostigmine. This is not the same as the dilation caused by atropine, but arises from adrenaline stimulating the terminations of the bronchial sympathetic fibres, which cause relaxation of the muscle.

Other Organs containing unstriated muscle are similarly affected, some undergoing contraction, while others are inhibited under adrenaline, and in each case the result corresponds with the effect of stimulation of the fibres of the sympathetic supply. A curious instance of the action of adrenaline has recently been described by Spaeth, who found that it induces contraction of the pigment in the scales of the small fish, fundulus.

The **Secretions** do not present such marked changes under adrenaline, though they are also generally increased when they are controlled by the sympathetic nerves. This is due to the fact that the blood supply is simultaneously reduced by the vaso-constriction, for Edmunds has shown that the secretion of the pancreas is arrested by adrenaline causing ischæmia of the gland. The saliva under adrenaline corresponds in character with that secreted on stimulation of the cervical sympathetic trunk, not with that from stimulation of the chorda

tympani, which is a cranial antonomic nerve and is therefore not susceptible to adrenaline. The *sweat* glands provide the most notable exception to the rule that adrenaline has the same effect as sympathetic stimulation, for though they are innervated by sympathetic fibres whose stimulation causes secretion, adrenaline has no effect on the sweat secretion, whether it is injected intravenously or applied locally. The nerves to the sweat glands are anomalous in another feature, for their terminations are the only example in which atropine paralyzes sympathetic terminations.

The secretion of the *urine* is often arrested immediately on the injection of adrenaline and is then considerably augmented. This appears to be due to the vascular action, the renal vessels being constricted at first but relaxing sooner than those of the other organs; the flow of blood through the kidney is thus reduced at first and the urinary secretion falls or stops altogether; then an abnormally large flow occurs from the renal vessels dilating while the blood-pressure is still high, and more urine is secreted accordingly.

The glycogenic function of the *liver* is disturbed by the presence of excess of adrenaline and the result is an unusual hydrolysis of glycogen and an unusual amount of sugar in the blood and tissues, which may give rise to glycosuria. This is not generally seen when a single intravenous injection is made, apparently because the action is too short; but it may be induced by the prolonged intravenous infusion of dilute adrenaline solutions, and very frequently arises from the subcutaneous injection of large amounts. This accelerated breaking down of glycogen appears to arise from adrenaline stimulating the terminal mechanism of the sympathetic nerves in the liver that control the glycogenic function. The action is thus of the same character as that in other organs and perhaps differs only in being slower and thus requiring a longer period of action than is necessary to induce obvious changes in the bloodvessels and unstriated muscle. The statement is sometimes made that the glycosuria does not occur after adrenaline in animals in which the thyroid glands have been excised previously, but this is not generally correct; the glycosuria is not a constant feature after adrenaline even in normal animals, and inferences from its absence ought to be drawn only with the grestest reserve.

Adrenaline thus acts in the same way as stimulation of the sympathetic nerves and is held to induce its effects by stimulating the mechanism lying between the nerves and the muscle. It obviously does not act on the contractile muscle itself, for some involuntary muscle contracts under it while in other organs it relaxes. And it is found that under ergotoxine, an alkaloid which antagonizes the action of adrenaline in some organs, the muscle remains active though the receptor on which adrenaline acts is paralyzed. Adrenaline therefore does not act on the contractile mechanism of muscle. On the other hand it does not act on the anatomical nerve ends, for after these have degenerated and disappeared, the usual effects of adrenaline are elicited by its injection. It is obvious that the action is exercised on some substance intermediate

between the nerve and the contractile material of muscle and this has been termed the "myoneural junction."

Adrenaline injected intravenously acts in very small quantities, $\frac{1}{1000}$ mg. often sufficing to raise the blood-pressure in the dog. The effect is of very short duration, but it may be repeated indefinitely by fresh injections, and this is generally agreed to be due to the rapid destruction of adrenaline in the tissues. Elliott states that this destruction takes place more rapidly in those organs in which adrenaline acts strongly than in others, and it certainly is not destroyed in the blood-plasma. When the blood-pressure regains its normal level after an injection of adrenaline, none of the alkaloid can be detected in the blood or tissues, the whole having undergone oxidation. Straub classes adrenaline among the "potential" poisons and holds that it acts only in the process of permeation into the cells which are affected by it; when it has reached the interior it is at once destroyed and the action, therefore, lasts only as long as there is adrenaline in the blood in excess. A new injection by increasing the concentration in the blood causes further permeation into the cell and renews the action.

Adrenaline applied locally induces such vaso-constriction that it is only slowly absorbed; and it, therefore, has only local effects when it is given by the mouth. Injected hypodermically it causes local ischæmia, and after large doses compared with those necessary by intravenous injection, a distinct rise of blood-pressure and some dilation of the bronchi often occur; injected intramuscularly it seems to have stronger general effects.

Animals are poisoned by large amounts injected hypodermically, and even smaller quantities induce glycosuria and diuresis. Larger quantities cause prostration, collapse and paralysis of the central nervous system, ending in failure of the respiration and œdema of the lungs. Similar symptoms arise from the intravenous injection of very large doses, but here the effects of the high blood-pressure are also in evidence in numerous hæmorrhages. The intravenous injection of adrenaline in the rabbit often leads to atheromatous degeneration of the aorta, apparently from the strain caused by the high arterial pressure; it does not occur in other animals.

A number of other substances are known which resemble adrenaline in action and in chemical structure. Many of these are formed by chemical synthesis, but some are found in nature, being produced from the amino-acids by the removal of the carboxyl group; the amino-acids are formed in the decomposition of proteins and where this occurs in the presence of putrefactive organisms these bases are liable to occur. The best known of these is **Tyramine** or hydrox-phenylethylamine which is formed from the amino-acid tyrosin.

$$\underset{\text{Tyrosine.}}{C_6H_4OH.CH_2CH(COOH)NH_2} = \underset{\text{Tyramine.}}{C_6H_4OHCH_2CH_2NH_2} + CO_2$$

Another artificial amine is **Epinine**, $C_6H_3(OH)_2.CH_2.CH_2NHCH_3$. These bases are all less active than adrenaline but otherwise present no significant divergence from it in their effects on the organism. Tyramine

is said to have slightly less action on the terminations of the inhibitory nerves, and to increase the blood-pressure more when it is injected hypodermically. Tyramine occurs in the ergot preparations and was first identified in putrefying flesh.

Preparations.—Extracts were at first made from the fresh glands, but soon the dried glands were introduced—*Suprarenalum siccum* (U. S. P.)—and a watery solution made from these may be used. The active principle has been put on the market under the name of ADRENALINE,[1] and this has almost entirely supplanted the cruder preparations.

ADRENALINUM (B. P.), $C_9H_{13}NO_3$, a light brown or nearly white powder very slightly soluble in water; it may be obtained from the suprarenal glands of animals or may be formed synthetically.

LIQUOR ADRENALINI HYDROCHLORICUS (B. P.), a one per 1000 solution with sodium chloride (0.9 per cent.), chloroform, and hydrochloric acid.

Therapeutic Uses.—Disease of the suprarenal gland leads to a series of symptoms known as Addison's disease, and it was hoped that the extract of the gland might counteract this condition by supplying the substance whose deficiency induced the symptoms. As a matter of fact, however, no success has attended its use for this purpose, and there is evidence that in Addison's disease the tissue at fault is not the medulla, from which adrenaline is obtained, but the cortex of the gland.

The general action of adrenaline on the circulation may be induced in such emergencies as heart failure, in which its powers of restoring the circulation have been proved both in animals and in man; for example, in animals in which the heart has been arrested by excessive doses of chloroform, the circulation may be restored by the intravenous or intracardiac injection of adrenaline (Gunn). The dose suggested for intravenous injection is 0.2 c.c. of liquor well diluted. In this connection it is to be borne in mind that adrenaline may tend to cause fibrillation of the ventricle at an earlier stage of chloroform anæsthesia. In inaccessible hæmorrhage, its intravenous injection might conceivably constrict the vessels and permit of the formation of a clot, but the great rise of pressure would tend to increase the hæmorrhage, and its use is therefore hazardous and has generally been found inefficacious.

Adrenaline has also been employed in "shock" to constrict the vessels; where the symptoms are largely nervous in origin, this may be good practice, but when true secondary shock has developed with capillary distention and reduced blood volume, adrenaline appears to be of no service, and the treatment should aim at increasing the volume of the blood in circulation by the transfusion of blood or the infusion of gum-saline.

The great use of adrenaline is, however, due to its local effects on the vessels. No other body is known which induces such complete contrac-

[1] Other names applied to this substance are adrenine, suprarenaline, vasoconstrictine, adnephrine, supracapsuline, hemostasine, suprarenine.

tion of the vessels in any part to which it is applied, and in addition it has practically only local effects, unless it is injected into the blood. Complete bloodlessness of a part may thus be elicited without significant alteration of the general blood-pressure, and in fact without any appreciable effect upon other parts of the body. This local ischæmia has been largely employed to allow of bloodless operations on the eye and to remove congestion of the conjunctiva from various causes. It is often administered with cocaine in operations on the eye (1 of adrenaline solution in 10). In congestion of the nasal mucous membrane and in operations on the nose it is also used extensively and with much success; the 1 per mille solution may be sprayed into the nose, or cotton soaked in it may be packed into the cavity. In epistaxis and in operations on the nose, the hæmorrhage ceases almost completely and the contraction of the mucous membrane permits of a clearer view of the field of operation. Hay fever is often temporarily relieved by similar treatment. A solution of adrenaline has been found useful in hæmorrhage from the ear, mouth, and throat, and in controlling hæmorrhage in operations in general surgery.

Grünbaum first suggested its administration by the mouth in gastric hæmorrhage, in which the action is confined to the mucous membrane of the stomach. Similarly it may be injected into the rectum, bladder and uterus in congestion or hæmorrhage from these organs, and Schäfer recommends it especially in post-partum hæmorrhage, in which it acts not only on the uterine vessels but also on the muscular walls, and arrests the bleeding by causing a tonic contraction. In all of these cases the adrenaline has to be applied directly to the bleeding organ. The local contraction of the vessels lasts very much longer than that induced by intravenous injection, for even dilute solutions cause ischæmia lasting from thirty minutes to two hours, according to the rapidity with which the adrenaline is absorbed. The vessels of some organs scarcely contract under adrenaline, and no benefit is to be expected from its application in hæmorrhage from these; spraying adrenaline into the lungs in case of hæmoptysis, for example, is quite useless, and similarly hæmorrhage in operations on the brain cannot be controlled by it.

The constriction of the vessels in a part to which adrenaline is applied retards the absorption of poisons injected with the adrenaline, and at the same time permits of their exercising a more marked local effect. This fact has been utilized in surgery to prevent the absorption of cocaine and to intensify its local action, and the method has been attended with most encouraging results. A few drops of the 1 per mille solution are added to the Schleich's solution of cocaine, and blanching of the tissues results; instead of cocaine, any of its substitutes may be used, as adrenaline does not interfere with their action.

The hypodermic injection of 1–2 minims of the liquor often gives relief in asthmatic attacks immediately; apparently enough of this large dose is absorbed to stimulate the inhibitory nerve ends in the bronchi.

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XVI. ERGOT.

Ergot is a parasitic fungus (Claviceps purpurea) which grows on the rye (Secale cereale) and occasionally on other kinds of grain; more rarely on other plants. It is of some importance in therapeutics and also in toxicology, as the use of bread and meal containing it has frequently given rise to widespread epidemics.

The chemistry of ergot has been the subject of a large number of investigations,[1] but the active principle has only been established by the recent work of Barger, Dale and their co-workers, who have isolated two alkaloids from the fungus. One of these, *Ergotinine*, $C_{35}H_{39}O_5N_5$, is almost inert, but its hydrate, *Ergotoxine*, $C_{35}H_{41}O_6N_5$, has a powerful action on the tissues. Either alkaloid can be readily transformed into the other, and this may explain many of the discrepancies in the literature of the subject.

In the ergot preparations there are found in addition *Tyramine* (page 378), *Ergamine* (page 388) and several other bases such as *Isoamylamine* and *Acetylcholine* (page 350). These often present in other conditions as products of the putrefaction of protein, and it is not yet determined whether they are formed by the ergot fungus itself or by the microbes which infest it. In any case they do not exert any significant action when ergot is applied by ordinary therapeutic methods. The effective agent is the ergotoxin.[2]

[1] These have generally resulted in the introduction of some supposed active constituent, but none of these were chemically pure and the names have now only historical interest. The best known of these names are ecboline, ergotine, sphacelinic acid, cornutine, chrysotoxine, secalintoxine, sphacelotoxine.

[2] It is stated that in some specimens of ergot, the ergotoxine and ergotinine are replaced by two isomeric alkaloids *Ergotamine* and *Ergotaminine* ($C_{33}H_{35}N_5O_5$) ,which are identical with them in their pharmacological activities but differ from them in their physical properties; the chemical relations between the two pairs are unknown.

Ergot has rarely given rise to serious **Acute Poisoning** in man, but in some cases in which it was taken to procure abortion the symptoms consisted in collapse, with a weak, rapid pulse, tingling, itching and coldness of the skin, unquenchable thirst, vomiting and diarrhœa, confusion or unconsciousness, hæmorrhage from the uterus, abortion and often icterus. Ecchymoses were found in the subcutaneous tissues and in many internal organs. Occasionally, after a single small dose, gangrene has supervened in small areas such as the toe-nails.

Given in therapeutic doses ergot has generally no effect except in pregnant women, in whom it often induces contraction of the uterus and evacuation of its contents. In some cases of fatal poisoning no abortion occurred.

Chronic Poisoning was formerly not uncommon, and in fact frequently gave rise to widespread epidemics, from the use of bread containing ergot after poor harvests and especially in wet seasons. Of late years these epidemics have become rare except in Russia, but some of the "plagues" of mediæval Europe may have been due to ergot poisoning.

The symptoms of ergotism are sharply divided into two groups: those of gangrene and those of nervous disorders. In some epidemics both the gangrenous and the convulsive forms are present, but, as a general rule, the epidemics in Western Europe were almost exclusively gangrenous in type, while in Eastern Europe the convulsive form almost invariably prevailed. The gangrene is generally developed in the limbs, especially in the fingers and toes; sometimes the whole arm or leg becomes cold and anæsthetic, dark in color, and then dry, hard and shrunken, and falls off with little or no pain and no hæmorrhage. Symptoms of such severity are rare, however, and in milder cases only the skin necroses. Gangrene of internal organs also occurs, resulting in cataract in the lens of the eye, or ulcers in the bowel and stomach, and sometimes affecting a whole organ such as a lung or the uterus. Abortion is seldom mentioned in the accounts of chronic ergot poisoning, and pregnancy seems in many cases to have run its ordinary course.

In spasmodic ergotism the first symptoms are depression, weakness and drowsiness, often with headache and giddiness, painful cramps in the limbs and itching and formication of the skin. In severe cases paroxysmal convulsions set in, generally clonic, and often epileptiform, but leaving as sequelæ contractures in the limbs, or less often in the trunk muscles. Some intellectual weakness often follows recovery from ergot poisoning, this not infrequently amounting to complete dementia, but the disease was immediately fatal in a large proportion of cases in earlier times. The characters and distribution of these two forms of ergot poisoning have given rise to much discussion. The gangrenous form appears to be the more characteristic, and it has been suggested that the spasmodic form may have arisen in cases where ergot poisoning was complicated by starvation and possibly by epidemic nervous disease such as poliomyelitis or meningitis.

In mammals treated with ergot, restlessness, salivation, sometimes

vomiting and purging have been observed. Depression and weakness, ataxia and clonic convulsions follow on larger doses, which prove fatal by paralyzing the respiratory centre. Gangrene is common in the pig, in which the ears, the extremities, and patches of the skin of the trunk become dry and hard, and finally fall off. Extravasations of blood into the stomach and bowel and other organs have frequently followed the exhibition of ergot in mammals. In pregnant animals abortion is often induced, but not invariably, even when very large doses are given.

In fowls a characteristic train of symptoms is induced, and these animals have frequently been used as tests for the activity of ergot preparations. The cock becomes drowsy and dyspnœic, and the comb and wattles become dusky purple in color. Vomiting or purging may follow and a curious ataxia is observed, the animal swaying to and fro and evidently maintaining its balance with difficulty. After large or repeated doses the comb becomes dry and hard and falls off, and a similar gangrene may attack the legs, tongue, or wings. The animal refuses food and becomes weak and somnolent, but may recover if the treatment be stopped. The gangrene of ergot poisoning arises from the prolonged constriction of the vessels by the ergotoxine.

Action.—The action of ergot or ergotoxine in the living organism has only recently been elucidated by the admirable experimental work of Dale, who showed that this alkaloid resembles adrenaline in some of its effects, and like it acts on the myoneural junctions of the true sympathetic nerves. But while adrenaline stimulates these junctions indiscriminately whether they are motor or inhibitory in character, ergotoxine does not act on the inhibitory junctions at all, and while stimulating the motor myoneural junctions in small doses, paralyzes them in larger amounts. It is less powerful than adrenaline, but its effects last longer and can be elicited by hypodermic injection or even by administration by the mouth.

Circulation.—Ergotoxine injected intravenously causes an abrupt rise in blood-pressure which is obviously due to action on the peripheral vessels, for it occurs after section of the splanchnic nerves, and is accompanied by constriction of the vessels of the abdominal cavity and the limbs, as may be shown by oncometer and plethysmographic records (Fig. 35, *A*). The heart is often accelerated at first and then slowed, partly from the vagus centre being stimulated by the high blood-pressure and partly by a direct action on the heart muscle. Sometimes the slowing of the heart may be so marked as to lower the blood-pressure and thus to conceal the effects of the vasoconstriction on the tracing.

The rise in pressure is to be ascribed to stimulation of the constrictor nerve terminations in the vessel walls and is strictly analogous to that observed under adrenaline. The extent to which it is developed varies in different animals, being well marked in the cat, dog and fowl and observed only with difficulty in the rabbit and monkey.

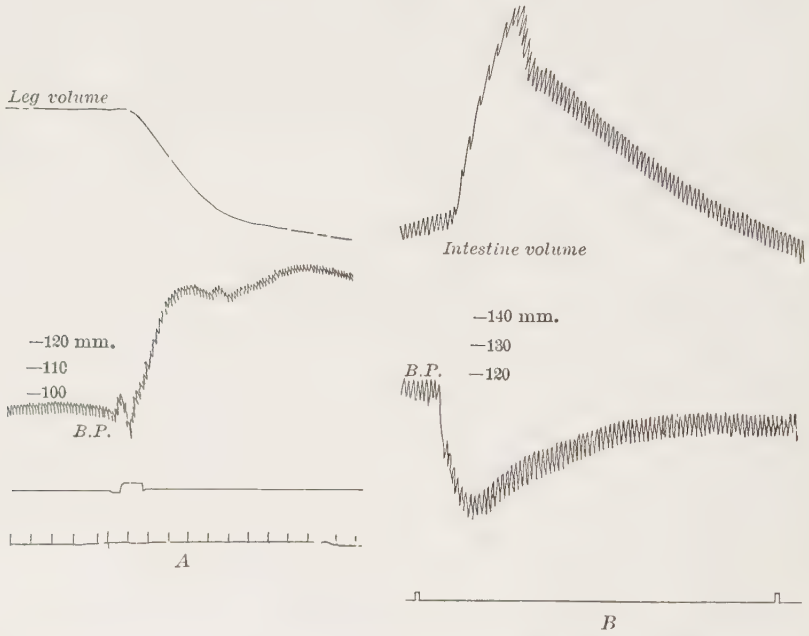
Ergot preparations injected intravenously sometimes fail to increase the blood-pressure if they contain little ergotoxine and large proportions

of ergamine, which dilates the capillaries (page 390). As a general rule an intravenous injection of an ergot preparation is followed by some fall in pressure, and then by a slower rise above the normal.

Ergotoxine has little effect in constricting the vessels when it is applied locally. The absorption is not so much retarded as by adrenaline therefore, and ergot action may thus be elicited by oral administration.

The heart is not acted upon so strongly as the vessels by ergotoxine but the contractions are strengthened while the rhythm is slower in some degree; it is uncertain how far this arises from direct action on the

Fig. 35



Figures illustrating the effects of ergotoxine on the blood-pressure (Dale). In *A* the injection induces a rise of blood-pressure (*B.P.*) with constriction of the vessels of the leg. In *B* a large dose of ergotoxine had been injected previously, and adrenaline injected at the point indicated now causes a fall of blood-pressure with dilatation of the intestinal vessels.

cardiac muscle and how far the accelerator terminations are involved. Crude ergot preparations generally slow and strengthen the heart when injected intravenously; sometimes a muscarine action is induced by the presence of acetylcholine. The terminations of the inhibitory nerves of the heart are not paralyzed or weakened in any way by ergot.

Stomach and Intestine. -Ergotoxine in small doses has little effect on the movements of these organs, since the sympathetic nerves are inhibitory and therefore escape its influence; under ergot vomiting and diarrhœa often occur in animals; in man the action on the digestive organs is seldom noticeable.

The **Pupil** undergoes a powerful constriction when ergot is injected intravenously, sometimes after a momentary dilatation. This constriction is not affected by atropine and arises from the direct action of ergotoxine on the muscle fibre; in the rabbit, however, the pupil is dilated, perhaps owing to the excitement and increased movement.

The **Respiration** is often greatly accelerated in poisoning in animals apparently from stimulation of the centre, though this may be aided by the increased movement and high temperature.

The **Temperature** rises greatly in the cat and rabbit under ergotoxine, while in the rat and mouse it often falls. The fever temperature is partly due to increased heat formation, partly to imperfect heat-loss (Githens); it is absent after removal of the brain, presumably owing to the destruction of the heat regulating centre.

In some animals the hair rises owing to the stimulation of the sympathetic terminations in the pilomotor muscles.

The most important effect of ergot, however, is exerted on the **Uterus,** in which it causes a powerful contraction which lasts for a short time and is followed by a slow relaxation interrupted by numerous new contractions, a lasting effect on the irritability being induced (Fig. 36). The innervation of the uterus, both motor and inhibitory is derived from the sympathetic; but ergotoxine, acting only on the motor fibres, always causes contraction, the inhibitory ones remaining unaffected by it.

The uterus thus reacts to ergot in a way precisely analogous to the arterioles, and it is noteworthy that from the uterus alone any very obvious symptoms are elicited by therapeutic doses. For the alimentary tract is but little affected, and the rise of blood-pressure is not easily observable in the circumstances in which ergot is usually exhibited. The contraction of the uterus in pregnant animals causes the descent of the fœtus toward the os, and in suitable doses ergot induces abortion. If the dose injected is small, the rhythmic contractions are accelerated and strengthened, or if the uterus is at rest, ergot may arouse it to rhythmic contraction. As the dose is increased, the contractions become more powerful and last a longer time, until with a large injection the uterus may contract very powerfully and remain in this position for many minutes.

The secondary paralyzing action of ergotoxine on the myoneural junctions is elicited only by large doses and does not occur in the therapeutic use of ergot; large quantities of ergot often elicit this effect in experiments, however. This paralysis affects only the motor sympathetic neurons, while the inhibitory ones are left unaffected and stimulation of a mixed motor and inhibitory nerve, or the injection of adrenaline, now causes inhibition only. Thus, after a large dose of ergotoxine, adrenaline lowers the blood-pressure (Fig. 35, B), while previously it increased it by stimulating the constrictor nerve ends; these are now unable to react from the paralyzing action of ergotoxine, but the dilator nerve ends are still unharmed, and adrenaline stimulating them dilates the vessels. Adrenaline also acted on the dilators before the ergotoxine injection, but the effect of this stimulation was masked by the simultaneous stimulation of the more powerful constrictors. The same reversal of effect by ergotoxine is seen if the splanchnic nerves be stimulated. The motor splanchnic fibres to the intestinal sphincters and bladder and other similar motor sympathetic fibres are similarly paralyzed

by ergotoxine in large doses, and stimulation of the nerves or the injection of adrenaline has now no effect on them. The fibres from the cranial and sacral nerves, however, are uninjured. Similarly, stimulation of the cervical sympathetic no longer dilates the pupil or elicits salivation in ergotoxine poisoning because the connection with the muscle and gland is broken, but the motor oculi and chorda tympani, being cranial nerves, remain normal. Both motor and inhibitory nerves of the uterus are sympathetic, and ergotoxine in large amounts paralyzes the motor while leaving the inhibitory intact: stimulation of the hypogastric nerve or adrenaline now causes inhibition and relaxation. The accelerator nerves to the heart are sympathetic, but it is difficult or impossible to throw them out of action completely with ergotoxine.

Some **Tolerance** is acquired for ergotoxine when it is injected repeatedly into animals.

FIG. 36

Tracing of the movements of the uterus under ergot injected intravenously at the point *E*. Contraction is indicated by an upward movement of the lever.

PREPARATIONS.

U. S. P.—**Ergota**, ergot of rye, the sclerotium of Claviceps purpurea replacing the grain of rye. When more than one year old, it is unfit for use.

Extractum Ergotæ, 0.25 G. (4 grs.).

FLUIDEXTRACTUM ERGOTÆ, 2 mils (30 mins.).

B. P.—**Ergota**, the sclerotium of Claviceps purpurea, originating in the ovary of Secale cereale. It should not be used if more than a year old. 15–60 grs.

Extractum Ergotæ (Ergotin), 2–8 grs.

EXTRACTUM ERGOTÆ LIQUIDUM, 10–30 mins.

INJECTIO ERGOTÆ HYPODERMICA, 5–10 mins. (subcutaneously). It contains 1 part of the extract in 3 parts of water and should be freshly prepared.

The fluid or liquid extracts and the hypodermic injection are the best of the preparations. A very large number of preparations, such as ergotin, ergotinic acid, sclerotinic acid, cornutine, etc., are simply more or less purified extracts and have no advantage over the pharmacopœial preparations.

The pure alkaloid, ergotoxine phosphate, has been put on the market and is used to a limited extent.

The crude preparations vary greatly in activity and appear to deteriorate

rapidly on keeping. At present they can be standardized only by comparing their activity on the uterus or blood-pressure of animals with that of a standard preparation or with that of the alkaloid.

Therapeutic Uses.—Ergot is used very largely in obstetrics to promote the contraction of the uterus, but considerable divergence is met with in the views of different authorities as to the special indications for its exhibition. Thus, those who believe that ergot increases the irritability of the uterus and produces rhythmical contraction without tetanus, advise that it be given whenever the pains seem insufficient, and more especially when this occurs in the later stages of labor. Others are possessed with an exaggerated apprehension of the prolonged uterine contractions, which they consider delay labor and tend to cause asphyxia in the child, and therefore advise that ergot be used only to preserve the uterus in a contracted condition after the child and placenta have been expelled. In every case the attendant should of course satify himself before giving ergot of the absence of all actual impediments to the passage of the child, such as contracted pelvis, abnormal presentation, or great rigidity of the soft parts, and when it is administered before the head emerges, the dose ought to be small, as otherwise the tonic contraction may be induced. When the head is about to emerge, on the other hand, a large dose may be given to promote the permanent contraction of the uterus and thus to prevent post-partum hæmorrhage. When the latter has once set in, ergot is of less immediate service, as it is slowly absorbed, and no effects follow for some twenty minutes or more. Whenever there is any reason to fear that weakness of the uterine contraction and hæmorrhage may set in after the expulsion of the child, ergot ought to be given when the head emerges, and many gynecologists recommend this as a routine treatment.

Ergot hinders post-partum hæmorrhage, chiefly by promoting the contraction of the uterus. In other forms of hæmorrhage—from the stomach, intestines, kidneys, lung or uterus—in which the bleeding point cannot be reached, it is often advocated in the belief that it contracts the walls of the vessels and thus arrests the flow of blood. These hæmorrhages so often cease spontaneously that it is difficult to estimate the value of any remedy, but it may be questioned whether ergot merits its reputation in these cases. There is no reason to suppose that a more intense action is exerted on a ruptured vessel than on the uninjured ones of other organs; but unless this is the case the use of ergot may be rather harmful than remedial, for any increase in the general blood-pressure, such as would follow the contraction of the vessels throughout the body, must increase the escape of blood from the injured vessel. The use of ergot in pulmonary hæmorrhage may be taken as an example: here ergot contracts the vessels very distinctly, and if the lesion lies beyond the part of the vessel which is contracted, that is, if the bleeding is capillary, the slower circulation may be beneficial; but the constriction of the vessels increases the pressure in the arterioles, and if the bleeding is arterial this augmented pressure may

actually increase it. Most clinical observers doubt the efficacy of ergot or any other vasoconstrictor in arresting internal hæmorrhage except from the uterus, and some advise the opposite treatment with vasodilators to reduce the blood-pressure (see Nitrite group). The essential treatment is rest with or without morphine. In these cases, as in labor, the fluidextract of ergot is often given by the mouth, but this extract or the special preparation of the B. P. is sometimes injected with the hypodermic needle. It is irritant, and ought, therefore, to be injected deeply into the muscle, rather than into the subcutaneous tissues.

The effect of ergot in inducing contraction of the uterus has been used in the treatment of subinvolution and of myomata of that organ; the involution of the uterus certainly seems to be favored by it, but the results in tumor are more open to question. In any case the prolonged treatment of this, or of any other condition, with ergot is to be deprecated, for if the drug is active at all, it may induce gangrene. The same criticism might be applied to the ergot treatment of a number of other diseases, such as aneurism, diabetes, or pneumonia; and in addition, it does not seem to have any greater effect in these than many other less dangerous remedies, which have been equally vaunted as specifics, and have been found equally valueless.

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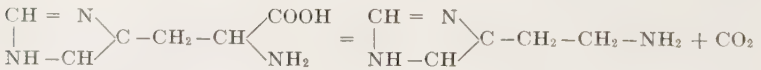
XVII. THE HISTAMINE GROUP AND ANAPHYLAXIS.

Histamine or Ergamine is an amine derived from the amino-acid histidin by the removal of the carboxyl group, and structurally is β-iminazolylethylamine.



Histidin. Histamine.

Histamine may be found wherever protein is broken down into its component amino-acids in the presence of putrefactive organisms; thus it occurs in some quantity in the intestinal contents and in the putrefaction of meats and has been isolated from preparations of ergot, though it is doubtful if it occurs in the fungus itself, and the quantity present is too small to modify the action except when the ergot is injected intravenously.

The action of histamine is very similar to that of a number of protein derivatives of unknown structure, such as peptones, the "split protein" produced by the action of alkalies (Vaughan), and the extracts of various organs and muscles. A very slight modification of the protein molecule

is sometimes enough to change it to a poison having the characteristics of this group; thus Bordet showed that serum shaken with agar agar induces poisonous symptoms of this type when injected intravenously, although it presents no other features which distinguish it from ordinary serum.

The symptoms of **Secondary Shock** from severe injury in man may also be included in the group, for they resemble those induced in animals by histamine so closely that it has been suggested that they are due to the liberation of histamine or similar poisons in the injured tissues.

Another form of poisoning which resembles that of histamine very closely was first described by Richet and called by him **Anaphylaxis**. If an animal receives an injection of any harmless foreign protein, it presents no symptoms whatever; but if the same protein is injected again after an interval of about fifteen days, severe or fatal poisoning may result. This anaphylactic reaction is very specific for each protein; for example, if the first, or sensitizing injection consists of horse serum, then the second injection must contain horse serum, that of any other animal causing little or no reaction. The sensitiveness to a second injection remains for many months, in man perhaps throughout life, and this has become of great importance of late years, since an injection of one of the antitoxic sera in childhood may suffice to induce fatal poisoning in adult life if a second treatment is necessary with serum from the same species of animal. When an animal recovers from even slight anaphylactic shock, no reaction occurs from a further injection; the animal is said to be desensitized.

Many unusual reactions presented by individuals to certain foods or to exposure to dusts and pollens which are harmless to most people, are now believed to be due to their having been previously exposed to these and having become sensitized to them. Anaphylaxis is induced only by proteins.

Several explanations of anaphylactic shock have been given; according to one of these, the first or sensitizing injection leads to the development of a ferment-like substance which modifies the protein injected (antigen); on the second injection this ferment decomposes it rapidly into a poisonous "anaphylotoxin" which produces the symptoms, just as such a drug as histamine does. On the other hand, Dale holds that the sensitizing injection leads to the formation of a new antagonistic body, precipitin, which penetrates into the cells of unstriated muscle and other tissues; when the second injection is made, the antigen penetrating into the cells reacts with the precipitin by a process akin to precipitation, and this induces the contraction of the muscle and other symptoms. This view is in harmony with many other facts known about the behavior of antigens and has been supported by experiments in which the involuntary muscle reacted to the second injection after all trace of protein had been washed out of the vessels, and in which any anaphylotoxin in the blood must have been removed also. In anaphylaxis then there is no new poison formed in the blood, but the cells are peculiarly sensitive to the presence of the antigen; it is true that this sensitiveness arises from

the formation of a precipitin in the blood and tissues as a result of the first injection, but this is not toxic in itself, but only reacts with the antigen. This precipitin may be transferred by transfusion to a second animal, which then becomes sensitive to the antigen, though it has never come in contact with it directly. After the shock has been recovered from, no second attack is caused by a second injection of antigen, since all the precipitin has been combined already.

The similarity of the symptoms induced by all of these has suggested that they arise from a single substance, and histamine has been looked for repeatedly in the tissues in anaphylaxis and shock, but in vain. There is no real justification for this view, for in many instances very similar symptoms may be induced by different bodies; for example, depression of the brain may be induced by such dissimilar drugs as chloral, morphine and magnesium.

Symptoms of histamine poisoning have arisen in man from attempts to substitute it for ergot in obstetrics. At the point of injection it causes swelling and infiltration of the tissues, which is itching or painful on pressure. Headache and depression are complained of, the face and head are congested, the conjunctiva is blood-shot and painful. The breathing is dyspnœic, and sticky mucus is expectorated. The blood-pressure falls while the pulse is accelerated. Nausea is developed and the stomach is found to be strongly contracted when examined by x-rays. Finally the impairment of the circulation progresses to profound collapse and shock, especially on any exertion being attempted.

In animals the effects of histamine vary with the species. In the guinea-pig an intravenous injection may be fatal within a few minutes owing to spasm of the bronchial muscle which prevents expiration, so that the lungs are found fully distended and do not collapse when the thorax is opened. In the rabbit the most severe symptoms arise from the constriction of the pulmonary arterioles, which causes dilation of the right ventricle and finally arrests the circulation. In the cat and dog histamine induces vomiting and purging, profuse salivation, dyspnœa and collapse; the pupils are constricted and the uterus contracts powerfully.

In all of these animal the **Central Nervous System** appears to be somewhat depressed, though this may be overshadowed by the symptoms arising from the peripheral organs.

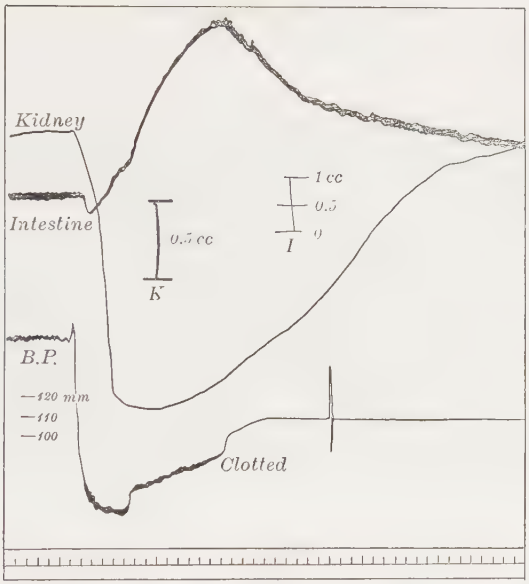
The action on the **Circulation** is complicated and differs in different animals. The arterioles are contracted and the blood-pressure is therefore increased in the herbivora, while in the carnivora this preliminary increase is absent or transient and is soon followed by a large fall in pressure from dilation of the capillaries. The rise in pressure is due to direct action on the muscle, which is not prevented by ergotoxine, the subsequent fall to a loss of tone in the capillary walls, which become distended with blood; the animal is bled into its own capillaries and this leads to the symptoms of collapse from insufficient blood returning to the heart and the arterial side of the circulation. The pulmonary vessels remain constricted however, and this is another factor in disturbing the

circulation. In the cat the capillary action is diffused fairly evenly throughout the systemic circulation; in the dog it is more marked in the liver than elsewhere as is shown by the swollen and tense condition of that organ.

In the herbivora, the action on the capillaries is absent, so that histamine increases the blood-pressure through constriction of the arterioles; later it becomes irregular through the asphyxia.

The capillary action is not developed when histamine is added to the fluid perfused through surviving organs of the cat in the ordinary way, apparently because some receptor in the capillaries has become unresponsive through the failure of the oxygen and adrenaline supply; in these

FIG. 37



The action of ergamine on the blood-pressure (*B.P.*) and on the volume of the intestine and kidney in the cat. The injection causes a marked fall in the blood-pressure which is due to dilatation of intestinal capillaries. The kidney vessels are constricted. (Dale.)

experiments, histamine lessens the flow through the vessels by constricting the arterioles. When special measures are taken, however, the dilation of the capillaries can be shown in these experiments also (Dale and Richards). The shock symptoms in carnivora are increased by anæsthetics, and this is true also of secondary shock from injury. The heart is increased in strength though it may be slowed in rate from a direct action on the heart muscle, but as the fall of pressure is developed, the beat may become slower from an insufficient supply of blood.

The **Respiration** does not seem to be affected through the centre; the asphyxia in the herbivora is induced by constriction of the bronchi from histamine acting on the bronchial muscle directly; this action is hardly

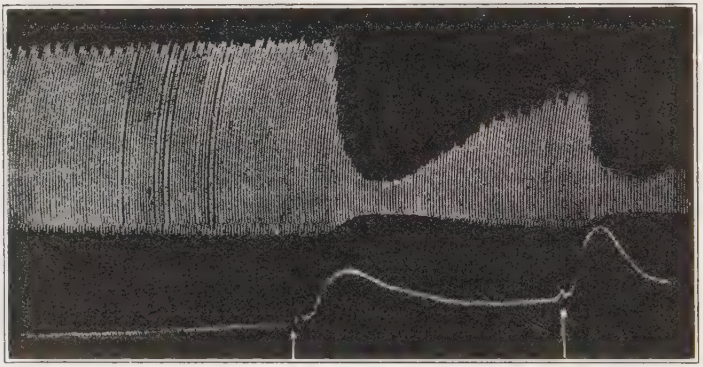
affected by atropine, showing that it is not dependent on the nervous mechanism; on the other hand, it is antagonized to some extent by adrenaline which inhibits the bronchial muscle, and by anæsthetics, especially urethane, which has a special weakening action on the bronchi.

The **Stomach and Intestine and Uterus** contract more powerfully or may pass into spasm, and as this effect is not counteracted by atropine, it probably arises from direct action on the muscle; the uterus is more sensitive to the presence of histamine than any other organ.

The pupil is contracted, apparently from central action, for this does not occur under anæsthesia.

Many **Glands** secrete under histamine—the salivary, gastric, pancreatic and lachrymal; this action is prevented in the salivary glands, and presumably in the others, by atropine, but not by section of the chorda tympani, so that the secretion is probably caused by stimulation of the ganglia or the terminations of the postganglionic fibres.

Fig. 38



Action of ergamine on the bronchi and blood-pressure of a rabbit. The expansion of the lungs on inflation is greatly reduced (upper tracing) from the contraction of the bronchi. The blood-pressure rises with each injection. At the arrows, intravenous injection of ergamine (Gunn.)

The accumulation of the blood in the capillaries facilitates the escape of the plasma of the blood, so that the red cells are increased in proportion.

Histamine is not found in the urine, but apparently is destroyed in part or completely in the tissues; it first loses the amine group (NH_2) and is then further oxidized to a harmless acid. Unless rapidly injected it is comparatively harmless owing to this change.

The local action of histamine is seen when it is applied to a scratch on the skin or by subcutaneous injection and consists in dilation of the capillaries leading to redness, swelling and the exudation of plasma into the skin; this is apparently due to local capillary dilation and suggests that the wheal caused by local injury may arise from the liberation of bodies with similar action.

The characteristic action of histamine is the powerful contraction of

the unstriated muscle, which is developed in the uterus,[1] and in the bronchi in some animals. The muscle of the alimentary tract and arterioles responds less strongly and the iris and bladder are not affected directly. In the carnivora there is extreme dilation of the capillaries, apparently from direct action on the walls, except those of the lungs. The peripheral nervous mechanism of the glands is stimulated to some extent, and there is some narcotic action on the brain.

The action of histamine and of other bodies resembling it in effects does not suggest any use in therapeutics, which is not more safely attained by other less dangerous measures. It has been tried as a uterine stimulant in doses of about 2 mgs. ($\frac{1}{30}$ gr.) given hypodermically, but even this dose causes unpleasant symptoms in some instances.

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XVIII. PITUITARY EXTRACT.

The extract of the pituitary body was shown by Oliver and Schaefer to exercise a pronounced effect when it was injected intravenously; the anterior lobe proved devoid of this action, which arises only from extracts of the posterior lobe or infundibulum and the intermediate tissue. Some authorities believe that there are at least two active principles in the extract, but neither has been isolated as yet and little is known of their characters beyond that they are comparatively simple but very unstable bodies which can be dialyzed and boiled without losing their activity. It has been suggested that they are related to histamine, but this has proved erroneous. These principles act in minute doses, smaller than those of any known substance except perhaps the protein poisons.

Action.—The administration by the mouth of the dried gland or its extract is not attended with any obvious result, while the intravenous injection of the aqueous extract causes pronounced effects in a number of organs, especially in those containing involuntary muscle.

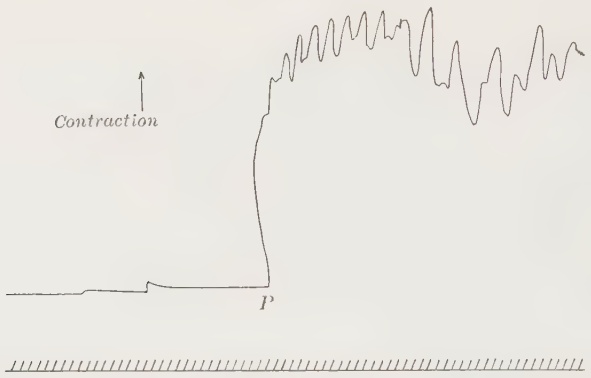
Circulation.—When the extract is injected intravenously, the blood-pressure rises rather slowly and remains elevated for some time. The rise is sometimes preceded by an abrupt fall, but this is probably due to some impurity and not to the essential principle. The rise in pressure is due to constriction of the peripheral arterioles, as is shown by the lessened volume of the organs. And as this constriction occurs after

[1] A remarkable exception to this contractor action has been observed by Guggenheim in the rat's uterus, which is inhibited by histamine.

the vasoconstrictor nerves have been divided and even after their connection with the muscular coats of the arterioles has been interrupted by ergotoxine, the pituitary substance must act directly on the muscle fibre. The rise in pressure under pituitary extract is smaller and less abrupt than that under adrenaline, but it is maintained longer. The constrictor action on the vessels may be shown by perfusing them with saline containing pituitary extract, when the venous outflow is at once reduced. All the arterioles examined appear to be constricted when thus perfused, but in the body they vary in their response, some being narrowed more than others and the renal vessels even being dilated.

The heart is generally slowed by the injection, and this partly through direct action on the cardiac muscle, and in smaller part from inhibitory action; the slight inhibitory stimulation may perhaps arise

Fig. 39



Contraction of the isolated uterus suspended in Ringer's solution; pituitary extract was added at *P*. (Dale.)

from the increased blood-pressure flooding the brain and arousing the inhibitory centre. But the extract also slows the excised heart perfused with Ringer's solution, which indicates that the muscle is directly affected. The sudden fall of blood-pressure which is sometimes observed immediately after the injection appears to be due to this cardiac depressant action.

After the blood-pressure has returned to its normal height, a second injection of pituitary extract is found to have no effect or a much slighter one than the first, the vessel walls apparently having lost their power of response to the active principle. Or the blood-pressure may fall instead of rising, owing to the presence of depressor substances in the preparation.

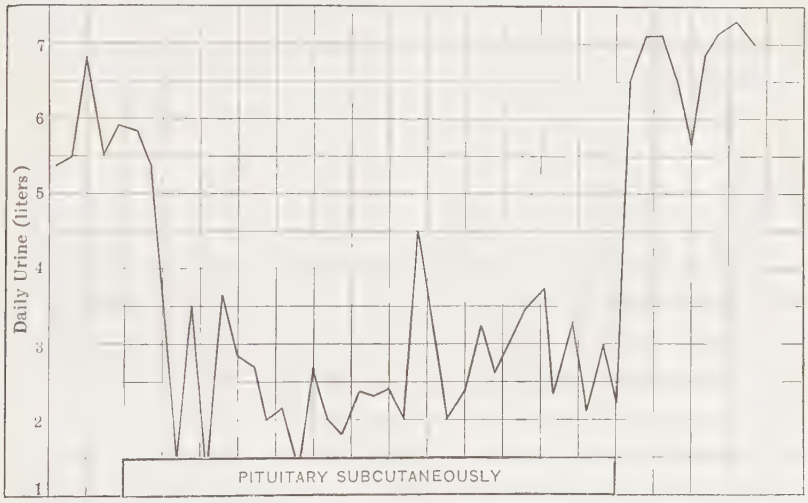
Respiration.—The respiration is generally strengthened at first, but later becomes shallower and slower, and these phases may recur several times. After repeated injections of the extract, it ceases to have any effect. The centre is acted on directly, the action beginning at the same time as that on the blood-pressure. In the rabbit and guinea-pig the

bronchial muscle is strongly contracted and may cause asphyxia in the same way as under histamine..

The **Stomach and Intestine** are aroused to stronger contractions under pituitary extract and their tone is increased, the relaxation being less complete. The bladder also undergoes similar changes.

The Uterus contracts more strongly and relaxes less completely after pituitary extract (Dale), and this change differs from that seen under adrenaline in that the stimulating action occurs in all animals, whether pregnant or not, and therefore cannot be attributed to action on the nervous mechanism but must arise from direct muscular effect. This action on the uterus follows from the hypodermic as well as from the intravenous injection of pituitary extract, and is more marked than the motor action on the alimentary tract.

FIG. 40



Urine in a case of diabetes insipidus in a child. The subcutaneous injection of pituitary solution, at first 0.25 c.c. three times daily, later 0.05 c.c. twice daily, reduced the urine from about 6 litres to 2.5 litres; the intake of fluid fell in the same proportion (Christian).

When frogs are treated with pituitary extract, a distinct darkening of the skin is observed from dilation of the melanophores or pigment masses; this appears to be due to a direct action on the pigmented cells.

The Pupil appears to vary in its reaction and shows no very marked change as a general rule; in the excised eye of the frog some observers obtained dilatation, other contraction; in the rabbit contraction generally occurs from intravenous injection, dilation from instillation (Pollock).

Kidney.—One of the earlier observations was that pituitary injection was followed by a profuse secretion of urine, this is accompanied by an accelerated flow of blood through the kidney, while the amount of oxygen used in the organ is not increased. The diuresis thus appears to arise not from direct action on the kidney itself, but from the larger

amount of blood passing through it, owing to the changes in the circulation. The urine sometimes contains sugar in animals, but this is not uncommon in diuresis from other causes. This diuresis in normal animals renders its effects the more remarkable in cases of diabetes insipidus. In this condition the urine is enormously increased, as much as 15–20 litres being passed in twenty-four hours or more than ten times the normal amount; this is accompanied by intense thirst and large amounts of water are drunk, in fact it is still unknown whether diabetes insipidus is primarily a very marked form of diuresis or a severe type of thirst. There is often some lesion in the pituitary or in neighboring parts of the brain. The hypodermic injection of pituitary extract reduces the urine to within ordinary limits and by repeated daily injections, this may be maintained, but the diuresis returns as soon as the treatment is stopped. It seems most likely that these injections simply act as substitutes for the natural secretion which is absent or deficient in these cases, but it is unknown how the diuresis is abated, whether by direct action on the kidney or through the brain.

Milk-secretion.—One unique property of pituitary extract is its power of increasing the secretion of the mammary glands. No other drug approaches it in this galactagogue effect. The rate of outflow may be increased as much as eighty times by an intravenous injection of pituitary extract and Schaefer states that even the glands of a non-pregnant cat may be induced to expel some serous fluid under its influence. Pituitary extract does not actually increase the amount of milk formed, but merely causes its rapid expulsion by arousing the unstriated muscle of the gland to contract; this is not prevented by atropine, the muscle fibres being affected directly. While the secretion is increased immediately, the total amount of milk per day is not augmented in cows. In the human subject pituitary extract injected intramuscularly causes tingling in the breasts and then free secretion. The extract of the pituitary of birds and fishes is also galactagogue in mammals.[1]

The **Central Nervous System** does not seem to participate in the action of pituitary extract except after very large doses, which are followed by some somnolence and muscular weakness. The cerebrospinal fluid is increased, apparently from a direct action on the choroid plexus.

The action of pituitary extract is apparently a direct one on the terminal organs in each case and not on the nervous mechanism. The failure of a second injection to induce effects comparable to the original one has not been explained in any way. The most typical effects are obtained by the intravenous injection of the extract, but subcutaneous injection also elicits them in a less marked degree. Little or no effect follows the administration of the gland or its extracts by the mouth.

General Metabolism.—The effects of the pituitary extract on the metabolism have not been adequately examined. It is not found that

[1] The other known galactagogues are extracts of the corpus luteum, pineal gland, involuting uterus, and of the lactating mammary gland itself, and these are less powerful than pituitary extract.

the growth of young animals is materially altered by its administration with the food.

The **Excretion** of the pituitary principle appears to be slow and to be performed by the kidney.

Preparations.

Hypophysis Sicca (U. S. P.), the powdered posterior lobe of the pituitary body of cattle, is a yellowish or grayish powder only partially soluble in water. Dose 0.03 G. ($\frac{1}{2}$ gr.).

Liquor Hypophysis, a solution of the water-soluble principles of the fresh posterior lobe of the pituitary body of cattle. It must be assayed biologically. (See p. 45.) Dose 1 mil. (15 mins.).

Various extracts of the posterior lobe are on the market under the names of Pituitrin, Infund bulin, Hypophysin, Pituglandol and Hypophysin sulphate.

Therapeutic Uses.—Pituitary preparations have been extensively used in obstetrics in order to arouse and strengthen the contractions of the uterus. The effects come on about three to five minutes after the subcutaneous injection; the contractions of the uterus set in moderately but increase in strength and the interval between the pains is shortened. The contractions themselves are of shorter duration but stronger and in some instances, at any rate, the relaxation is less complete between the pains. The extract is used chiefly to arouse an inert uterus but has also been injected after delivery in order to prevent post-partum hæmorrhage by inducing contraction. It is used as a substitute for ergot in short, and is said to be less liable to cause tonic contraction of the uterus, though this may prove to be erroneous on further experience. It may be injected in one or in several doses and as much as 3 mils of pituitrin has been used without injury; it must first be ascertained that there is no obstruction to the passage of the child.

The diuretic action of pituitrin is less available for clinical use, as the repeated injection of the drug is scarcely possible and it has little effect when given by the mouth. Its effect in increasing the milk outflow is also not yet made use of in medicine and the same objection holds against its employment for this purpose. It has been employed in some cases of shock to raise the blood-pressure. It seems unlikely to be of value to arrest hæmorrhage owing to its raising the blood-pressure.

In the failure of the intestinal peristalsis which sometimes follows extensive operation, pituitary extract has been injected with good results.

Pituitary extract is stated to have been beneficial in certain forms of atrophy of the hypophysis and in symptoms which are referred to a lowered efficiency of the gland. Very large amounts have been given in some of those cases without any deleterious effects. Finally, pituitary extract has been used to lessen the excessive secretion of urine known as diabetes insipidus, and there can be no doubt of its efficacy here; it must be given by subcutaneous injection at least twice a day.

Other Organic Extracts (Organotherapy).

In recent years numerous extracts of animal organs have been introduced into therapeutics, but with the exception of the preparations of the supra-

renal, pituitary, thyroid glands and quite recently of the pancreas, they have proved disappointments. The theory on which many of these have been evolved, shows little advance upon the belief of the savage that the courage of the lion may be acquired by eating the animal's heart, and the clinical observations which have been cited to support their use, have generally been of an equally primitive order. The atrophy or destruction of certain organs unquestionably gives rise to marked and even fatal symptoms: for example, atrophy of the suprarenal bodies leads to Addison's disease, and castration involves certain structural changes in distant organs. But in neither of these instances can these sequelæ be averted by the use of the extract of the excised organs: they may possess internal secretions, but these cannot be utilized in therapeutics, possibly because of their rapid destruction. Probably no more fruitful source of quackery exists than in the exploitation of these so-called remedies, and among them all the extracts of the testicles and ovaries stand preëminent; introduced by Brown-Sequard in 1889 on insufficient observations, the testicular extract has been employed as a sort of panacea, which among other qualities, restored to age the fire and vigor of youth. All accurate observations agree that this extract is entirely devoid of value in therapeutics.

Further advance is to be looked for in the use of these extracts, but can only be made through careful observation and experiment, which alone has given us the useful remedies of this class which are now available. The indiscriminate and haphazard use of these organ-extracts in every sort of disease has not led to any progress in the past, and will hardly be more successful in the future.

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XIX. HYDRASTINE AND HYDRASTININE.

Hydrastine is an alkaloid which occurs in Hydrastis Canadensis (Golden Seal) along with two other alkaloids, *Berberine* and *Canadine*. Hydrastine ($CH_2.O_2$-$C_9H_7NCH_3.C_{10}H_9O_4$) is readily decomposed into *Hydrastinine* ($CH_2O_2C_9H_7NCH_3$) and opianic acid. Chemically hydrastine is nearly related to *Narcotine* ($C_{22}H_{23}$-NO_7), one of the opium alkaloids, which differs from it only in the possession of another methoxyl group; and narcotine can also be decomposed into *Cotarnine* ($C_{12}H_{15}NO_4$) and opianic acid, cotarnine differing from hydrastinine again only by a methoxyl. Another opium alkaloid, *Laudanosine*, undergoes a similar decomposition and the resulting alkaloid has been shown by Laidlaw to resemble hydrastinine in action. The effects of the three original alkaloids, hydrastine, narcotine, and laudanosine in the body also present many similarities.

Action.—**Hydrastine** causes in frogs an increase in the reflex irritability and eventually tetanus exactly resembling that produced by strychnine, and like it terminating finally in paralysis.

In mammals the pulse is slowed by comparatively small quantities, while somewhat larger doses cause general feebleness, tremor, dyspnœa, and inco-

ordination in the movements. Very large quantities elicit clonic and then tonic convulsions and tetanus, during which the respiration ceases. The pulse is slowed at first from stimulation of the vagus centre, is afterward quickened from its paralysis, and still later becomes slow again from direct action on the cardiac muscle. The blood-pressure rises from constriction of the arterioles but afterward falls from the weakness of the heart. Hydrastine injected intravenously arouses the uterus to contractions, which are sometimes rhythmic in character, but sometimes assume a prolonged tetanic form; the action is a local one, for it also occurs in the excised organ. Hydrastine is excreted as such in the urine. When it is administered for some time, a cumulative action is said to be developed.

Canadine in small quantities produces depression and drowsiness followed by complete recovery without further symptoms. In larger quantities v. Bunge found that it caused a short stage of excitement, which was followed by depression and paralysis of the central nervous system. It has little or no effects on the mammalian circulation when administered in ordinary doses, but very large quantities cause weakness and arrhythmia of the heart. Its injection is followed by violent peristalsis of the intestine and diarrhœa. Canadine is present in only very small quantity in the Golden Seal and has apparently little importance in therapeutics.

Hydrastinine differs from hydrastine in causing no marked disturbance of the centres of motion and feeling save in enormous doses, which paralyze the nervous system. The heart is slowed and strengthened by small doses, apparently from direct action on the muscle, and the output is increased. This causes a small rise in the blood-pressure, and another factor leading to the same result is a slight constriction of the arterioles through a direct action on the muscular coats; this slight constriction is observed also on perfusing the surviving organs. The action on the blood-pressure is not very marked, however, even when large doses are employed.

The most important action of hydrastinine is that on the uterus, which increases in tone and often contracts rhythmically and powerfully under its influence. This occurs also in the excised organ and is due to a direct action on the uterine muscle. There is apparently another effect due to stimulation of the ganglia on the fibres of the hypogastric nerves supplying the uterus, for in the non-pregnant cat, Laidlaw observed an inhibition of the organ from hydrastinine which could be removed by large doses of nicotine. This nervous action is not of importance, however, in the pregnant uterus in which hydrastinine is used chiefly, and in fact would here reinforce the direct muscular effect. Archangelsky states that a 10 per cent. solution of hydrastinine applied locally causes dilatation of the pupil, which reaches its maximum in two to three hours, and lasts for twelve to fifteen hours.

Cotarnine differs from hydrastinine in not constricting the vessels or strengthening the heart, so that the blood-pressure falls under it. The action on the uterus also seems rather weaker. The base obtained from laudanosine resembles hydrastinine exactly in action.

Preparations.

Hydrastis (U. S. P.), **Hydrastis Rhizoma** (B. P.), the rhizome and roots of Hydrastis Canadensis, Golden Seal, containing 2.5 per cent. of hydrastine (U. S. P.).

Hydrastinæ Hydrochloridum (U. S. P.) a white soluble salt with a bitter taste, 0.01 G. ($\frac{1}{6}$ gr.).

Hydrastininæ Hydrochloridum (U. S. P.), 0.03 G. ($\frac{1}{2}$ gr.), given in solution hypodermically or by the mouth, or in pills or tablets.

Cotarninæ Hydrochloridum (U. S. P.), Stypticine, Styptol, a yellow crystalline powder. 0.06 G. (1 gr.).

Therapeutic Uses.—Hydrastis has been used as a stomachic bitter and the large quantity of berberine contained in it would seem to give it a place

along with the simple bitters. It has also been credited with some obscure action on the mucous membranes when locally applied, through which it is said to benefit many forms of catarrhal inflammation; for this purpose the glycerite may be used. Besides various conditions in which its use was attended by doubtful success, it has been used in hæmorrhage from the uterus; but for this purpose hydrastinine ought to be preferred, as it acts more strongly on the uterus than hydrastine. The conditions in which it is indicated seem to be moderate hæmorrhage; for example, hydrastinine may be of value in excessive menstrual flow, while in post-partum hæmorrhage it seems to have little effect. In other forms of hæmorrhage, these drugs appear to have no value whatever. Hydrastine and hydrastinine have not attained any assured position in therapeutics, for at best they can only be considered inferior substitutes for ergot, which has a much more decided action on the vessels and the uterus. Cotarnine is inferior to hydrastinine and might be dismissed.

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XX. THE NITRITES.

The nitrites have a powerful action on the arteries, which they cause to dilate by depressing the muscle of the walls.

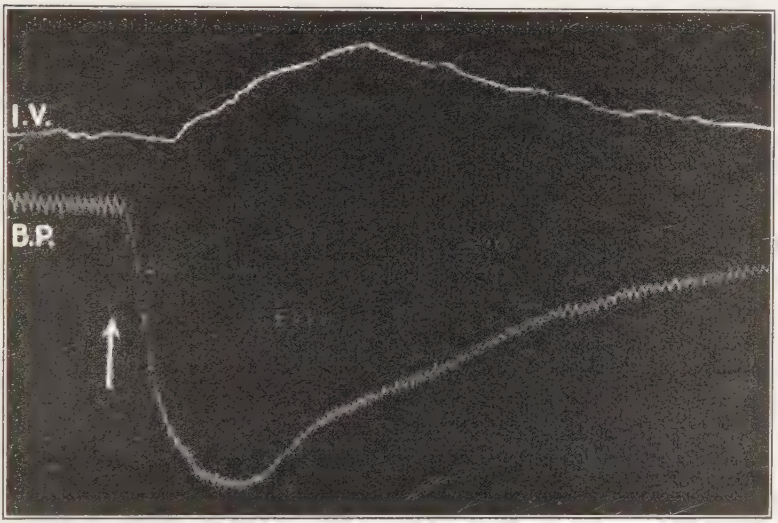
Those which have been examined more carefully are the *Nitrite of Sodium* and the *Nitrous Esters* of the methane series, especially the *Nitrite of Amyl*, which is largely used in therapeutics. In these compounds the radicle —NO is attached to the metal or alkyl. through an atom of oxygen, the formulæ being Na—O—NO, CH_3—O—NO, C_3H_7—O—NO, C_5H_{11}—O—NO, etc., and the chief constituent is the O—NO, the metal or radicle being of less importance. A closely allied series of bodies are the nitrates, in which the nitrogen has five valencies and is connected again to the metal or radicle by oxygen, Na—O—NO_2, CH_3—O—NO_2, C_5H_{11}—O—NO_2, etc. The metallic nitrates differ entirely from the nitrites in their effects and are used as diuretics (p. 300). Some of the *Nitric Esters*, however, undergo reduction when brought into contact with organic matter, and nitrites are thus formed, so that these bodies have effects very similar to those of the true nitrites, and have to be discussed along with them. The best known of such nitrates is the so-called *Nitroglycerin*, which is really the trinitrate of glycerin, ($CH_2(ONO_2)CH(ONO_2)CH_2(ONO_2)$), and is broken up by alkalies into a mixture of nitrates and nitrites. The nitrates have practically no action in the small quantities given, so that almost all the effects of nitroglycerin are due to the nitrite formed. Many other organic nitrates also form nitrites in the tissues, but none of them with such rapidity as nitroglycerin.

Two which have been used to some extent in the last few years are solids —*Erythrol Tetranitrate*, and *Mannitol Hexanitrate*. They act much more slowly and for a longer time than nitroglycerin.

Another series of bodies which may be mentioned as occasionally acting like nitrites, although more feebly, are the nitro-bodies. In these the nitrogen is attached to the alkyl directly, and not through the intervention of an oxygen atom. Examples of these are Nitromethane, $H_3C—NO_2$, and Nitroethane, $CH_3—CH_2—NO_2$. Their action is so feeble as to preclude their use in therapeutics, and seems due to the $—NO_2$ being split off in the tissues.

The best known member of the group is **Amyl Nitrite**, and its action will first be described, while the points in which the effects of the other members diverge from it will be discussed later.

FIG. 41



Tracing of the blood-pressure (B. P.) and intestinal volume (I. V.) in a cat. Amyl nitrite was inhaled at the point marked with an arrow. The blood-pressure falls, while the volume rises from the dilation of the splanchnic vessels.

Symptoms.—After the inhalation of a few drops of amyl nitrite, the face becomes flushed, and the patient complains of a feeling of fulness and throbbing in the head. Some headache and confusion is often present, the pulse is accelerated, and the respiration is somewhat quicker and deeper. The flush is often confined to the face and neck, but sometimes spreads over the whole trunk, and passes off in a few minutes, unless the inhalation is continued. If large quanitites of the drug be inhaled at once, however, or if the inhalation be continued for some time, a feeling of giddiness, weakness and eventually stupor follow, the pulse becomes slow, while the respiration still remains accelerated but is shallower and often somewhat irregular; convulsive movements may occur, but in general large quantities may be taken without actual danger in the human subject. The blood is said to have assumed a dark color in some cases, but this seems to be rare.

Action: Circulation.—The flushing and dilatation of the arterioles of the head is found to be accompanied and followed by a profound fall in the blood-pressure in man and animals. The heart is accelerated at the same time, and therefore is not responsible for the change. The cause, as has been repeatedly demonstrated, is the dilatation of the peripheral vessels, both arterioles and veins widening very considerably under the influence of the drug; the vessels of the abdominal organs and the face are more affected than those of the extremities. The vasomotor centre is not concerned in the widening of the vessels, for if amyl nitrite is allowed to pass through the medulla without reaching the peripheral vessels, no fall of pressure occurs. And stimulation of a constrictor nerve such as the splanchnic still produces some rise in the blood-pressure, so that the nerve terminations seem to be intact. The seat of action of amyl nitrite is therefore the unstriated muscle of the arteries and veins. No satisfactory explanation has been offered for the fact that in the skin only the vessels of the head and neck should be dilated, but other facts seem to indicate that these vessels occupy an exceptional position as regards their innervation and their reactions to drugs. Darwin was the first to point out that the blush of amyl nitrite corresponds in extent with the blush produced by emotion. This blush effect seems due to the amyl in part, for other amyl esters induce it, though none to the same extent as the nitrite. The direct action on the vessel walls may be easily shown by passing blood into the artery of the amputated extremity of an animal, and measuring the amount coming from the veins. If a few drops of amyl nitrite are added to the perfused blood, the outflow from the vein is greatly increased, although here no nervous mechanism can be concerned.

The acceleration of the pulse is more marked in man and the dog than in other animals, and is the result of the fall in blood-pressure which induces anæmia of the brain and thus depresses the tone of the inhibitory cardiac centre and probably excites the accelerator apparatus. The coronary arteries of the heart are dilated along with those of other parts of the body, but the blood supply to the heart is reduced.

Large quantities of amyl nitrite slow and weaken the contractions of the heart, owing to a direct depressing action on the muscle. In the frog, the heart is usually slowed from the beginning of the application.

The **Respiration** is generally accelerated, and at the same time rendered deeper by amyl nitrite. Not infrequently the breath is held at first, owing to a reflex from the nasal mucous membrane, but this is not so marked as in the inhalation of more irritant vapors, such as chloroform or ether. The acceleration is the result of the fall in pressure lessening the supply of blood to the brain and arousing the respiratory centre. After long inhalation the respiration becomes slower and shallower and in animals death occurs from asphyxia. The walls of the pulmonary vessels are less affected by the nitrites than those of the systemic circulation, and any change which occurs in the pulmonary blood-pressure is probably the indirect result of the acceleration of the

heart. The bronchial muscle is apparently relaxed by the inhalation of amyl nitrite or by the administration of other members of the group by the stomach, for relief is given in asthma. An old method of inducing this effect is by burning paper impregnated with saltpeter and inhaling the fumes, which contain nitrite formed by the reduction of the nitrate.

The **Kidneys** are not much affected by this series; occasionally a slight increase in the urine is observed, at other times a decrease, and after large quantities anuria may occur. These effects are evidently due to the changes in the calibre of the renal vessels. A small quantity may widen them when they are too contracted to allow of the maximal secretion, while on the other hand, if the normal calibre is the optimal, a nitrite may lessen the secretion by lowering the general blood-pressure. When large quantities lower the pressure, they inevitably lead to a lessened secretion or anuria.

Fig. 42

Blood-pressure under amyl nitrite taken on a slow drum in order to demonstrate the recovery. The whole tracing occupied some six minutes. The rapid fall of pressure is followed by an almost equally rapid return to normal. (Cash and Dunstan.)

Small quantities of amyl nitrite seem to have no action whatsoever on the higher parts of the **Central Nervous System.** The throbbing in the head and slight confusion are evidently due to the fall in general blood-pressure. The sight is curiously affected in some people, for when a dark object on a white background is looked at, it seems surrounded by a yellow ring and that again by a blue one. In the beginning the medullary centres may be slightly acted on reflexly from irritation of the nasal sensory terminations, and later the fall in blood-pressure and consequent anæmia of the medulla lowers the activity of the inhibitory centre for the heart and stimulates the respiratory and vasomotor centres. The spinal cord is not acted on in mammals, but is depressed in the frog.

After large quantities convulsions are often observed; these seem to be of cerebral origin, and are probably due to the circulatory changes and the formation of methæmoglobin.

The **Peripheral Nerves** and the **Muscles** are unaffected by the inhalation of amyl nitrite, but when the frog's muscles are exposed to the direct action of the vapor, they undergo a slow, passive shortening and rigor, and on periodical stimulation the contractions become rapidly weaker, until finally no response is made to the electric shock. Involuntary muscle is more easily affected than striated fibres, as has been shown by the behavior of the intestine and ureters, but even these seem less readily paralyzed than the muscle of the vessel walls, the depression and paralysis of which lead to the fall in the arterial tension, as has been already stated. The nerve terminations seem to be unaffected even by very large quantities, so that as long as a contraction of the muscles can be

elicited by direct stimulation, it follows also on stimulation of the motor nerve, and the vagus terminations in the heart can transmit impulses so long as the heart continues to beat. The **Temperature** is somewhat lowered by the nitrite series, owing to the dilatation of the skin vessels, but this fall is insignificant.

During the fall in the blood-pressure, the **Blood** is diluted by the lymph pouring into it from the tissues, while as the pressure rises the concentration returns to the normal. The nitrites change the hæmoglobin to methæmoglobin and nitric-oxide-hæmoglobin giving a dark chocolate color. This does not entail the destruction of the red corpuscles, and the compounds are eventually reduced by the tissues, although the reduction progresses much more slowly than that of ordinary oxyhæmoglobin. In man, usually very little of the hæmoglobin is thus transformed, and even after large quantities have been inhaled no abnormal coloration of the blood is noticeable, but the alteration of the

FIG. 43

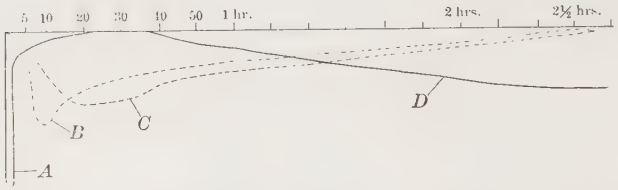


Diagram to illustrate the intensity and duration of the action of the members of the nitrite series. The extent of the fall of pressure is measured along the vertical, the duration along the horizontal line. *A*, amyl nitrite, ethyl nitrite, etc.; *B*, nitroglycerin; *C*, sodium nitrite; *D*, erythrol tetranitrate. The greatest fall in pressure occurs in *A*, but it passes off for the most part in five minutes and entirely in twenty. Nitroglycerin acts more rapidly than the last two, and its effects continue almost as long as those of sodium nitrite. Erythrol tetranitrate only exerts its full effect after the action of the others has passed off. (After Bradbury.)

hæmoglobin is the cause of death in some animals, through the blood becoming incapable of carrying oxygen to the tissues. If, however, asphyxia be prevented by the inhalation of oxygen under pressure, the tissues themselves are eventually acted on. The formation of methæmoglobin does not seem to bear any relation to the action of the nitrites on the vessel walls and is identical with that caused by other reducing bodies, which have no action on the bloodvessels.

Excretion.—After absorption into the blood, amyl nitrite seems to break up with the formation of nitrites of the alkalies. These undergo partial oxidation and appear in the urine in the form of nitrates and nitrites, but the quantity of these excreted is never equal to the nitrite absorbed, so that it seems probable that some part undergoes still further change. The amyl disappears, and is probably oxidized completely, although some may appear in the breath.

Nitrite of amyl given by the stomach is much less active than

when inhaled, as the nitrous acid is freed by the gastric juice and immediately decomposed. When injected subcutaneously it acts much more slowly and weakly than when absorbed by the lungs, and generally gives rise to glycosuria and slight diuresis. No satisfactory explanation of this fact has been given, but it is possible that the formation of methæmoglobin may cause partial asphyxiation of the tissues, and thus cause the formation of excess of lactic acid and glycosuria.

The pharmacopœial amyl nitrite, is a mixture of the nitrites of amyl, butyl, propyl, and ethyl. The pure nitrites of this series resemble each other closely in general features; the more unstable the compound, the more rapidly does the fall in blood-pressure occur, while the less easily decomposed compounds are somewhat slower in their action, but cause depression of the blood-pressure for a longer time.

Sodium Nitrite resembles the organic nitrites closely in action. It is administered by the stomach, and therefore acts more slowly than amyl nitrite, but its effects last much longer. The gastric juice liberates part of the nitrous acid before absorption can occur, and it is immediately decomposed and often causes some eructation and may also give rise to irritation of the gastro-intestinal mucous membrane. The nitrite absorbed is excreted as nitrate in the urine, although some of it may remain unoxidized. The metallic nitrites do not as a rule cause so much headache and flushing of the face and neck as the alkyl compounds.

Nitroglycerin produces the same effects as the other members of this series, but acts more powerfully than either the metallic or alkyl nitrites. It presents some minor points of difference, as in causing more severe headache in man. It is not decomposed in the stomach, but on reaching the blood, at once breaks up into glycerin, nitrites and nitrates. Its action commences very soon after its administration, and lasts much longer than that of amyl nitrite. The explanation of its greater activity may be that it is absorbed unchanged, but is then broken up at once, while the metallic nitrites are decomposed in the stomach and much of the nitrous acid is lost. Nitroglycerin is not wholly broken up in the human body, however, for it has been found in the urine, and the headache which so frequently follows its administration in man has been ascribed to the undecomposed molecule, and not to the nitrite constituent. It is generally supposed to be extremely poisonous, and is prescribed in minute doses, but it has been shown that while very small quantities are sufficient to produce therapeutic effects in man, the toxic dose is enormous in animals.

Several other organic nitrates have also been found to reduce the blood-pressure, and to cause the formation of methæmoglobin, but their decomposition proceeds more slowly than that of nitroglycerin and they have not been much used in therapeutics. Erythrol tetranitrate and mannitol hexanitrate act more slowly, and the fall of pressure is more gradual, and lasts longer than under any others of the series.

Preparations.

Amyl Nitris (B. P.), Amylis Nitris (U. S. P.), a yellow, very volatile fluid, with a strong, fruity odor, soluble in alcohol and ether but rapidly decomposed by water. It consists of the nitrite of isoamyl for the most part, along with small quantities of the nitrites of butyl, propyl, etc. 2–5 mins. are poured on a handkerchief and inhaled. A convenient preparation is the amyl nitrite "pearls," which are thin glass capsules, each containing a dose of the remedy, and one of which is broken in the handkerchief when necessary. Amyl nitrite is liable to decompose when kept long, and ought to be used only when recently prepared. 0.2 mil (3 mins.).

Spiritus Glycerylis Nitratis (U. S. P.), Liquor Trinitrini (B. P.), is a 1 per cent. alcoholic solution of nitroglycerin. 0.05 mil (1 min.); B. P., $\frac{1}{2}$–2 mins.

Tabellæ Trinitrini (B. P.), or nitroglycerin tablets, are formed of chocolate and contain each $\frac{1}{100}$ gr. of nitroglycerin. 1–2 tablets.

Sodii Nitris (U. S. P., B. P.) ($NaNO_2$), 0.06 G. (1 gr.); B. P., $\frac{1}{2}$–2 grs., in tablets or in solution.

Spiritus Ætheris Nitrosi (U. S. P., B. P.), sweet spirit of nitre, contains 4 per cent. of ethyl nitrite, along with ether and aldehyde in alcoholic solution. When freshly prepared it acts like the other nitrites, but when prescribed along with water, as is usually the case, the nitrite escapes rapidly, and it has little effect except from the ether and alcohol. 2 mils (30 mins.): B. P., 15–60 mins.

Erythrol tetranitrate ($CH_2ONO_2(CHONO_2)_2CH_2ONO_2$) is a solid, and is recommended in doses of 0.05 G. (1 gr.), in pills, tablets or alcoholic solution. Like nitroglycerin, it is a dangerous explosive, and one fatality has already occurred in forming it into pharmaceutical preparations.

Therapeutic Uses.—The nitrites were introduced into therapeutics by Brunton, who advised their use in angina pectoris to relieve spasm of the arteries. Some question has arisen as to whether angina pectoris is generally accompanied by high arterial tension, and amyl nitrite often gives relief in cases in which the blood-pressure does not seem abnormal, so that the mechanism of its action is not completely determined. For rapid transient effects nitrite of amyl seems specially indicated, while nitroglycerin and nitrite of sodium are more suited to produce a depression of some duration. Thus during the attack of angina pectoris, amyl nitrite is often found to give instant relief, but if nitrite of sodium or nitroglycerin is administered every four to six hours, no attack may occur. The disadvantage of the metallic nitrites is the frequent eructation they produce, while nitroglycerin often causes severe headache, which, however, disappears in some cases after repeated use. The pulse assumes the dicrotic character under all of the nitrite series, owing to the reduced peripheral resistance (Fig. 44).

Besides in angina pectoris, the nitrite series may be used in any condition in which it is supposed that the arterial tension may be lowered with benefit to the economy. Thus nitroglycerin has been advised in heart disease and has accordingly been placed by some among the heterogeneous group of "Cardiac tonics or stimulants." Its beneficial effects are not due to any direct action on the heart, but to its decreasing the resistance against which the systole is performed. In this way the contraction of the ventricle is rendered more complete, and the output of the heart may be increased. In weak hearts strug-

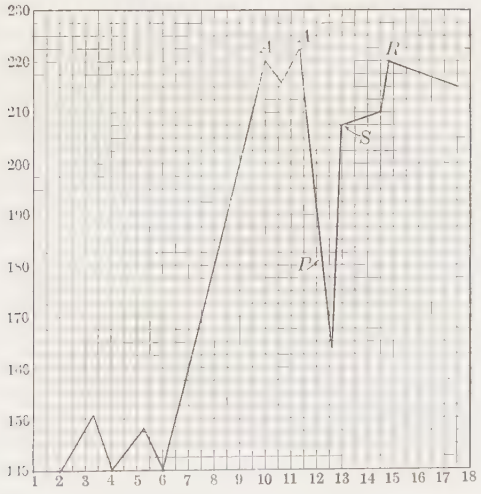
gling against a high aortic resistance, this relief may be followed by marked benefit, and for this reason nitrite preparations (nitroglycerin) are often prescribed in chronic Bright's disease. Stewart has shown that the flow through the peripheral bloodvessels is accelerated by

FIG. 44

Pulse tracing in a case of angina pectoris; *a*, before; *b*, during the inhalation of amyl nitrite.

nitroglycerin. Amyl nitrite has been advised in accidents during chloroform anæsthesia on the theory that it would benefit the circulation; but, as a matter of fact, it would appear strongly contra-indicated, in these cases, in which it is true that the heart is extremely depressed, but in which the arterial tension is practically zero. Its use is especially irrational if, as has been suggested, the failure of the

FIG. 45



Blood-pressure chart during an attack of angina pectoris. The pressure, originally 140 to 150 mm. of mercury, rapidly rose to 220, and intense pain was present over the heart. At *A* and *A*, amyl nitrite was inhaled and the pressure fell to 165 mm. At *P* the pain had disappeared. The pressure rose again rapidly and at *S* the pain recurred slightly and was very severe at *R*. Time in minutes.

respiration is partly due to anæmia of the central nervous system. The cases in which recovery has occurred after this measure may, in fact, be said to have recovered, not owing to, but in spite of the use of amyl nitrite.

Amyl nitrite has been suggested in internal hæmorrhage, on the view that by reducing the pressure in the interior of the vessels it would permit a clot to form at the point of injury. On the other hand, the dilatation of the abdominal vessels may lead to anæmia of the brain and syncope, and this has prevented the use of the drug in practice, except in unusual conditions.

In very advanced degeneration of the cardiac muscle fibre, the administration of amyl nitrite is distinctly contra-indicated, for the blood-pressure is low and any further reduction may lead to syncope from anæmia of the brain, and to still greater weakness of the heart from the low pressure in the coronary arteries lessening its nutrition.

Nitrite of amyl has been used largely in asthma and in cardiac dyspnœa. Its action is often beneficial and has been attributed to its depressing the bronchial muscles, which are supposed to be in a condition of spasmodic contraction in asthma. In the cardiac cases its action in removing the dyspnœa may be due to its lowering the pressure in the systemic arteries and thus relieving the heart.

In some cases of headache, nitrite of amyl is of marked benefit, while in others it aggravates the condition. This is perfectly intelligible, as some forms of headache may be due to cerebral congestion and peripheral constriction, while others arise from anæmia of the brain.

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XXI. THE DIGITALIS SERIES.

The digitalis series embraces a considerable number of substances which are characterized by their action on the heart. They are widely distributed in the vegetable kingdom in very different botanical families, and have long been in use for various purposes in civilized and uncivilized countries. Some of them were employed as remedies by the laity long before their virtues were recognized by the medical

profession, while others have been used as arrow poisons and ordeal poisons by the natives of different parts of Africa and of the Eastern Archipelago.

The most important plants which contain bodies belonging to this group are *Digitalis purpurea* (purple foxglove), *Strophanthus hispidus*, or *Kombé*, and *Scilla maritima* (squills). Others which are less frequently used are *Helleborus niger* (Christmas rose), *Convallaria majalis* (lily of the valley), *Apocynum cannabinum* (Canadian hemp), and *Adonis vernalis* (pheasant's eye). Similar effects are obtained from bodies contained in other species of these genera and in a large and ever-growing list of other plants, such as *Antiaris* (Upas tree), *Nerium* (oleander), *Acocanthera* (ouabaio), *Erythrophlæum* (sassy bark or Casca bark), *Thevetia*, *Cheiranthus* and *Coronilla*. Numbers of other plants are said to resemble digitalis in their effects, but until this has been shown by more careful investigation, it is undesirable to add them to the above list, which is already extensive enough. These bodies are not, however, confined to the vegetable kingdom, for Faust and Abel have isolated substances from toads, which induce the same changes in the heart. Salts of barium also induce many of the changes characteristic of this series.

The active principles of the plants of this group present many points of resemblance, and some of them have been shown to be derivatives of the same chemical nucleus. Their isolation is attended with considerable difficulty, as many are amorphous, and but few of them form combinations with the ordinary chemical reagents. Almost all of them are glucosides, one is an alkaloid. Several distinct bodies belonging to this series may occur in one plant and may be accompanied by others which induce the same symptoms as saponin.

Digitalis has been more carefully examined from the chemical point of view than the other plants, but even its active principles are still imperfectly known, and the subject is in an unsatisfactory state. The pharmacopœial preparations are made from the leaves, in which *Digitoxin* is the chief glucoside possessing the characteristic cardiac action, and is probably accompanied by one or more less clearly identified glucosides (*Digitalein* or *Gitalin*) which act on the heart less strongly, and by some others (*Digitsaponin*, *Gitin*) resembling saponin in effect and like it tending to suspend insoluble bodies in water. Digitoxin, the most powerful of the digitalis glucosides, is soluble in alcohol, but not in water when pure, while digitalein is soluble in both water and alcohol. The tincture of digitalis contains the whole of the active principles of the leaf, and these may also be obtained by an infusion, although the official one often fails to extract the leaf completely.

The seeds of digitalis are not pharmacopœial, but are extensively used for the preparation of the so-called digitalins of commerce. They are stated to contain another cardiac glucoside, *Digitalin*, and digitalein in large amounts with a small percentage of digitoxin and *Digitonin*, another glucoside resembling saponin in character. The preparations from the seeds thus differ from the Galenical preparations, which are

formed exclusively from the leaves, and most clinicians find them less satisfactory in practice.

The various species of **Strophanthus** contain glucosides which present differences in chemical form and also in toxicity but resemble each other in their common action on the heart. The species in common use are Strophanthus Kombé and Strophanthus hispidus, whose glucosides are known as *Kombé-strophanthin* and *Hispidus-strophanthin*. Strophanthus gratus (or glaber) contains a crystalline glucoside known as *Ouabain* or *Gratus-strophanthin* (*g-strophanthin* of Thoms)[1]. The strophanthin of commerce is generally derived from a mixture of different species and varies in composition.

Scilla maritima, or squills, contains a glucoside *Scillarin*, or perhaps more than one, which have not been isolated. Saponin bodies are also present.

Convallamarin (obtained from Convallaria), *Adonidin* (Adonis), *Oleandrin*, *Neriin* and *Neriodorin* (Nerium), *Euonymin* (Euonymus), *Antiarin* (Antiaris), *Thevetin* and *Cerberin* (Thevetia), *Cheiranthin* (Cheiranthus), *Coronillin* (Coronilla), *Tanghinin* (Tanghinia venenifera) *Cymarin* (Apocynum) and Helleborein (Helleborus) are glucosides, while *Erythrophlœine* (Erythrophlœum guinense) is an alkaloid.

With the exception of the last, then, the members of this series which have been examined hitherto are glucosides containing carbon, hydrogen, and oxygen, but no nitrogen. When kept long in watery solutions, and especially when heated with acids, they are liable to decompose into a sugar and a body with only feeble action on the heart. It must be noted that but little is known of the chemistry of these principles beyond their glucosidal nature, and few of them have any claim to be identified chemically.

Symptoms.—Digitalis taken in even large medicinal doses in health provokes no symptoms unless the dose is frequently repeated. Poisonous quantities induce nausea and vomiting with abdominal pain, and often diarrhœa. The patient complains of general depression, headache, giddiness and precordial discomfort and often passes into a stage of great muscular weakness and collapse. The pulse first becomes intermittent and then beats regularly at about 40 per minute. Later, it may become rapid and irregular, and fatal coma follows. The symptoms sometimes appear only several hours after the poison has been taken and last for several days in cases which survive.

A much more common form of poisoning arises from the prolonged use of therapeutic doses. Here the chief symptoms are headache, giddiness, nausea and vomiting and in some cases marked slowing of the pulse. These symptoms disappear within forty-eight hours if the treatment is stopped or the dose reduced.

Action.—The digitalis series possesses a local and a general action. The **Local Effects** consist in primary irritation, followed frequently by paralysis of the sensory nerve endings. Thus in the eye a small quantity of a solution, or a minute particle of the dry poison causes the most intense pain, redness and congestion of the conjunctiva, and all the symptoms of acute inflammation. On the tongue the bitter

[1] Ouabain is also obtained from some species of Acocanthera.

taste is followed by burning pain frequently, and if the powder be drawn into the nostrils and larynx, marked swelling of the mucous membrane, sneezing, coughing and hoarseness are produced in many persons. They have little action on the skin, although here too smarting is occasionally produced; but when injected subcutaneously many of them cause marked inflammation, which not infrequently ends in the formation of abscesses, even although the injection has been absolutely aseptic. This irritant action is not equally marked throughout the series, however, for digitoxin is much the most powerful in this respect, while digitalin may be injected subcutaneously without danger and almost without pain. The local anæsthetic property is likewise not equally developed in all the members of the series; several of them have been suggested as local anæsthetics for the eye, but their primary irritant effect precludes their use for this purpose.

After absorption, the chief symptoms are due to their action on the central nervous system and the heart. The action on the **Central Nervous System** consists in stimulation of some of the nerve centres, which is independent of the action on the heart and is limited to the medulla oblongata in many cases. In the frog the excitability of the reflexes is often lowered by members of this series, probably because of the intense stimulation of the medulla oblongata; but sometimes a distinctly increased irritability is observed. More marked symptoms are produced in mammals, however, by this central nervous stimulation, for in these vomiting is elicited very soon after the injection of large quantities, long before the heart is very seriously affected, and this is undoubtedly due to action on the medulla oblongata. To the same cause is to be attributed the rapid, deep respiratory movements and convulsions, which are often observed in the later stages of poisoning and which are evidently not due to cerebral anæmia, as has been supposed, for the brain at this stage receives quite as much or more blood than it normally does. Even small quantities, such as are used therapeutically, excite the inhibitory cardiac centre in the medulla and slow the heart both in therapeutics and in experiments on mammals. The extent to which the members of this series act as stimulants to the nervous centres varies, but as yet little comparative work has been done in this direction.

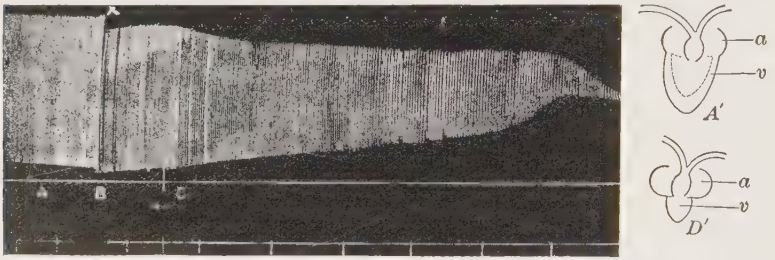
The action on the **Heart** is the most important of all, and is what distinguishes digitalis and its allies from all other substances. This action has been studied most carefully in the frog, and is here found to consist of changes in the generation and conduction of impulses and in the contractility. The power of conducting impulses is distinctly reduced, and this makes itself evident in the frequent failure of an impulse to pass from the auricle to the ventricle, which thus remains at rest during a full cycle; very often each alternate impulse of the auricle thus fails to reach the ventricle, giving rise to half rhythm; or the ventricle may remain in diastole during a series of auricular contractions, or may cease altogether in this position, if very small quantities have been injected. This depressant action on conduction is

accompanied by a less marked reduction of the rate of the auricle and sinus arising from fewer impulses being emitted by the pacemaker.

Along with this depression of conduction, there is a progressive increase in the strength of contraction of both auricle and ventricle. Soon the relaxation becomes imperfect, and the output falls accordingly; though the ventricle continues to empty itself more completely, it no longer contains as much blood at the beginning of systole as before. Later the apex of the ventricle remains contracted during the diastole and remains motionless and white, and this state of contraction slowly spreads over the rest of the chamber, until the ventricle receives no more blood from the auricular systole, and the auricles, unable to empty themselves, come to a standstill in the dilated position.

As a general rule both these actions may be observed intermingled in the frog's heart under digitalis; the effects of the depressed conductivity generally precede those of the changed contractility and are

FIG. 46



Tracing of the movements of the frog's ventricle under one of the digitalis series. *A*, normal; *B*, digitalis applied; *C*, half rhythm begins, and the diastole rapidly becomes less complete until the ventricle ceases in a position of semicontraction. *A′*, diagram of the heart in normal condition; *a*, auricle; *v*, ventricle; the dotted line represents the outline in full systole; the continuous, the outline in diastole. *D′*, outline of the heart in standstill after digitalis; the ventricle, *v*, is fully contracted, while the auricles are dilated. (After Sluytermann.)

elicited especially by very small doses. Thus when the minimal lethal dose is given, the ventricle is very often found in diastolic standstill from its failure to receive impulses from the auricle; but if it is now stimulated mechanically or electrically, it passes into complete and permanent systole. When larger quantities are given the effects on contractility are elicited in greater measure, and there may be little tendency to ventricular intermission until the chamber is in almost complete systolic arrest.

The excitability of the frog's heart muscle is augmented by digitalis; thus if salt solution is led through the excised heart for some time, it ceases to beat, but if digitalis is now added to the perfusing solution rhythmical contractions often return. This increased excitability may account for a temporary acceleration of the heart rate which is sometimes seen in the frog under digitalis.

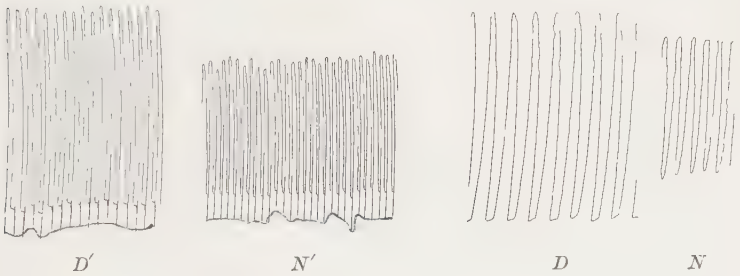
The action on the frog's heart is a direct one on the muscle; the

inhibitory mechanism has nothing to do with the change in the conduction or with that in the contractility, for the application of atropine has no effect upon either feature. The muscle of the frog's heart is thus reduced in conductivity and augmented in contractility and excitability by members of this series; the effect on the conductivity is elicited by smaller quantities than are necessary to change the contractility.

The hearts of some invertebrates are said to undergo changes similar to those described in the frog's heart, while the crustacean's seems to be entirely unaffected by digitalis.

Mammalian Heart.—In the mammalian heart digitalis and its allies also affect the muscle directly, but this is complicated by inhibitory action, which is absent in the frog. The direct action on the heart muscle in the healthy mammal is shown in increased strength of contraction and greater excitability, while there is less evidence of the depressed conduction which has been described in the frog's heart. Symptoms of reduced conduction occur in the mammal it is true, but here they arise for the most part from inhibitory stimulation and not from direct muscular effects.

FIG. 47



Tracings of the ventricular contractions under digitalis in experiments on two dogs. *N*, *N′*, normal contractions. *D*, *D′*, contractions under digitalis. The levers move upward during systole. In *D* the rhythm is slower and the movements extend further upward and downward than in *N*, *i. e.*, the contractions are more complete and the dilatation during diastole is greater. In *D′* the rhythm is slower, and the tracing extends further upward than in *N′*, but reaches almost the same point below, *i. e.*, the contraction is stronger, but the dilatation is scarcely changed. Contrast the effects of inhibition alone if Figs. 30 and 32 (pp. 331 and 348).

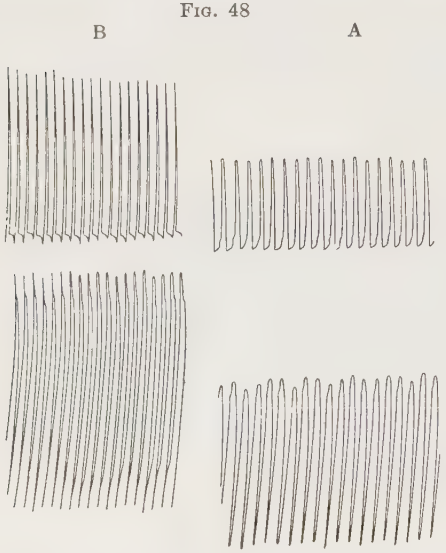
The action of digitalis on the healthy mammalian heart may be divided into three stages, of which the first and third are always developed when sufficient quantities are administered. The second stage may be absent in certain circumstances, but is also generally present in poisoning.

In the *first or therapeutic stage* of the action of this series (Fig. 47), the rhythm of the heart is distinctly slower than before the drug, for the inhibitory apparatus is set in activity, and the slowing is accordingly due to a prolongation of the pause in diastole. The ventricles contract to a smaller size, that is, they empty themselves more completely than they normally do. This increased contraction

is, like that in the frog's heart, due to action on the cardiac muscle. The papillary muscles undergo the same changes as the rest of the ventricular wall, contracting more strongly and more completely than before the administration of the drug.

The relaxation of the ventricle is found to vary in different conditions. If the heart is weak and dilated, digitalis and its allies tend to lessen this dilatation, that is, the relaxation of the ventricle during diastole is less than before the administration of the drug. (See Fig. 48.) If, however, the heart is normal, or does not dilate much during diastole, digitalis increases the relaxation (Fig. 47, *D*). The variation in the degree of dilatation of the ventricle depends upon the opposing factors—the inhibition and the muscular action. If the inhibition be the stronger, the ventricle relaxes more completely than before, for vagus stimulation always tends to increase the relaxation of the heart. If, on the other hand, the muscular action predominates the relaxation is lessened, for here, as in the frog's heart, this series tends to lessen the extent of relaxation. In the normal heart the application of one of this series causes, as a general rule, an increase in the extent of relaxation.

FIG. 48



Tracings of the movements of the ventricle (lower) and auricle (upper) under digitalis. During systole the levers make an upstroke. In this experiment the inhibitory terminations had been paralyzed, so that only the muscular action is developed. *A*, normal; *B*, after digitalis. The rhythm of the heart is slightly accelerated in *B*, and the levers extend further upwards, indicating a more perfect systole in both auricle and ventricle. The ventricular lever does not reach so far downward in *B*, *i. e.*, the ventricular diastole is less complete.

It must be added that the inhibition is due to the stimulation of the vagus centre in the medulla only; the peripheral mechanism is little involved, for digitalis hardly slows the heart after section of the vagi, as it would do, if it acted on the intracardiac inhibitory ganglia or nerve ends.

Each beat of the ventricle thus expels more blood under digitalis than before (Fig. 49), and if the number of beats per minute remained the same, the amount of blood expelled (or the output) would be much increased; but the rhythm is slower than normal, and this may more than compensate for the larger amount of blood expelled by each individual beat. In the therapeutic stage the slowing is not great

enough to counterbalance the increased output per beat, and a larger amount of blood is therefore driven into the aorta and pulmonary artery.

The changes in the ventricle, then, are due to inhibitory activity and to direct cardiac action, the first tending to lessen the number of beats and to increase the relaxation of the fibres, the second tending to strengthen the systole and to limit the relaxation while not affecting the rhythm.

In the auricles the inhibitory stimulation causes more or less increase in the dilatation, while it lessens the contraction. The muscular action is the same here as in the ventricle, causing a tendency toward more complete systole and less complete relaxation. After small quantities, the rhythm of the auricle is slow, like that of the ventricle, owing to the inhibition; the relaxation is little changed, but, owing to the muscular action, the contraction is more complete. In but slightly larger quantities, however, the inhibitory action causes a less complete contraction, so that the work done by the auricle is actually less than before the injection.

FIG. 49

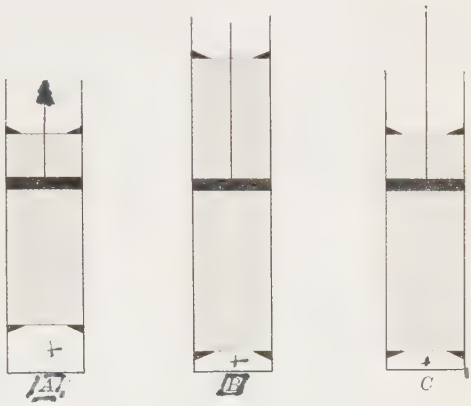


Diagram to illustrate the effect of digitalis on the output of the ventricle. *A*, *B*, *C*, three cylinders with pistons moving up and down in them and driving out fluid. In *B* and *C* (digitalis action), the piston descends lower than in *A* (normal) and in *B* it can also rise higher. The output of each stroke is represented by the shaded part of the cylinder and is greatest in *B*, in which more fluid is present at the beginning of the stroke (diastole) and less at the end of the stroke (systole) than in *A*. It is also greater in *C*, in which the same amount of fluid is present at the beginning of the stroke (diastole) as in *A*, but less is present at the end (systole). If the pistons make the same number of strokes per minute in *A*, *B*, and *C*, the amount of fluid pumped will be greatest in *B* and least in *A*, which represents the normal ventricle.

The rhythm of the different parts of the heart is exactly the same during this stage, and the changes seen in the right auricle and ventricle correspond to those in the left. The conduction of impulses from the auricle to the ventricle may be slower owing to the connecting fibres being depressed by the inhibitory activity.

Some observers state that small quantities of digitalis change the electrocardiogram, in certain features, but these changes are not constant and have received no adequate explanation, so that they do not require discussion at present.

If larger quantities be injected, either the inhibitory or the muscular action may become increased, and the appearance of the heart varies according to which of these predominates. It must be distinctly understood that the following symptoms betoken a grave condition of poisoning.

In the *second stage* the symptoms are due to excessive inhibitory activity, while the direct cardiac action is less developed. The rhythm of the ventricle, and consequently of the pulse, is very slow and irregular, as is always the case when the inhibitory apparatus is strongly stimulated (see Fig. 30, p. 331). During diastole the ventricle dilates more completely than usual, while its systole continues powerful, since the inhibitory stimulation increases the relaxation but has less power to diminish the contraction. Each beat expels more blood than normally, but the rhythm is so slow that the output per minute and the efficiency of the heart as a pump is less than usual. This is the feature which differentiates the first from the second stage, in which the same factors are present; in the first stage the efficiency of the heart, *i. e.*, the amount of blood expelled per minute, is greater, in the second stage it is less than before the administration of the drug.

Very often the impulses have difficulty in passing from the auricle to the ventricle (heart-block) owing to the inhibition of the conducting fibres. The ventricle then beats at a slower rate than the auricle, but if the irritability of the ventricle is increased at the same time as the conduction falls, there may arise a spontaneous rhythm in the ventricle, which is independent of, and different from, that in the auricle.

The auricular contractions are much weaker than in the first stage, and even than in the normal heart, and may cease altogether for some time, while the chambers do not tend to dilate further as a general rule.

This stage of excessive inhibition is not observed in every case of poisoning in animals, nor probably in man, although in the recorded instances of poisoning with the members of this series, it seems to have been present, as the pulse is said to have been very slow and irregular. If the inhibitory mechanism is weak, or is paralyzed by the preliminary injection of such drugs as atropine, the second stage is entirely absent.

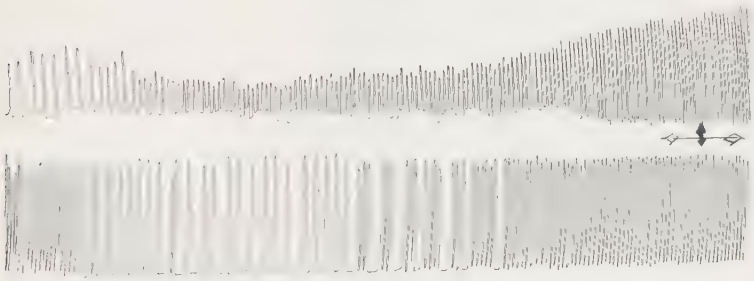
When very large quantities of any of this series are injected, the *third stage* sets in. It is preceded by the first for a short time, generally by both first and second. In this stage the ventricular rhythm becomes very much accelerated, often beyond the normal, and even beyond that seen after paralysis of the inhibitory nerves. This acceleration is not produced by paralysis of the vagus, for stimulation of this nerve sometimes still slows the heart and always causes dilatation. It is really due to the drug increasing the irritability of the heart muscle to such an extent that the inhibitory apparatus is no longer able to hold it in check.

The auricles also undergo the same changes. They begin to accelerate their rhythm, which may diverge from that of the ventricle, and the difference in rhythm of the two divisions leads to a very characteristic periodic variation in the strength of the contractions of both auricle and ventricle (Fig. 51). This auriculo-ventricular arrhythmia may continue for some time, but further irregularities soon present themselves. At intervals extrasystoles of either ventricle or auricle appear, that is, two contractions follow so rapidly on each other that

the chamber has no time to dilate fully between them and no blood is expelled by the second one. These extrasystoles become more numerous, and soon form groups of two or three, separated by other groups of ordinary contractions. The rhythm becomes more rapid and more irregular and this culminates in fibrillation of the auricle and ventricle.

All the features of the third stage are due to the poison increasing the spontaneous excitability of the heart muscle. This increased excitability in the pacemaker leads to acceleration of the beat of the whole heart, but larger amounts arouse the normally dormant areas in the auricle and ventricle, and lead to impulses being discharged from them and causing contractions of abnormal origin and irregular rhythm. In the ventricle this increased excitability leads to the development of a rapid spontaneous rhythm (Fig. 51), extrasystoles and finally fibrillation.

FIG. 50



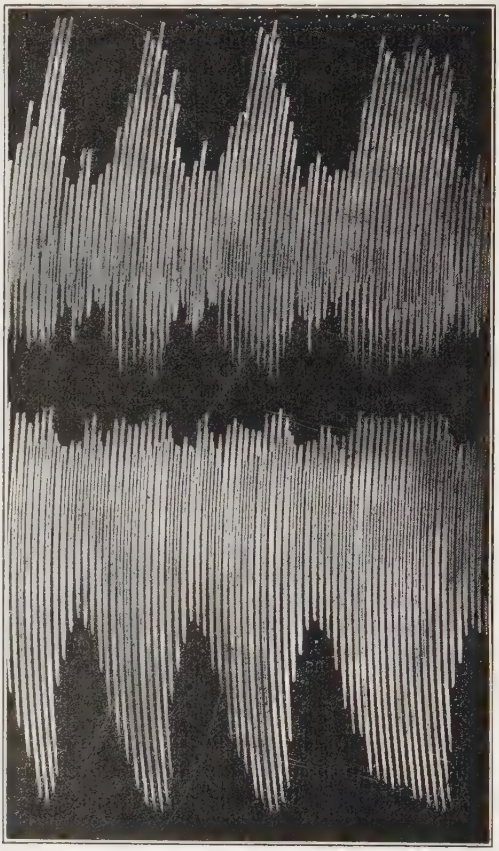
Tracing of the auricular (upper) and ventricular movements (lower) under digitalis, as the first stage passes into the second. During systole the levers move upward, during diastole downward. The rhythm of the two chambers is at first the same, but soon changes. the auricle maintaining its rapid beat while the ventricle becomes slow and irregular. At the end of the tracing the ventricle again becomes rapid, while the auricle becomes slow. The strength of the contractions and the extent of relaxation of the ventricle muscle remain little altered, while the auricle rapidly weakens in strength, but improves again at the end of the tracing.

Almost all the characteristic features of this stage may be imitated in the normal, unpoisoned heart by stimulating the different chambers by electric shocks; the impulses which in the poisoned heart arise from its own excessive irritability, are here given by the artificial stimuli, but the effect is the same. In this third stage the conduction from auricle to ventricle is reduced or completely destroyed, and this change differs from the impairment of the conduction seen in the earlier stages in being due to the direct action on the muscle and not to the inhibitory mechanism. In fact in the third stage the latter is not an important factor, the increased excitability and decreased conduction both arising from the direct heart action.

Throughout the whole course of the intoxication the ventricles beat in unison, and the two auricles also maintain the same rhythm throughout, but the rhythm of the ventricles may, as has been stated, be entirely different from that of the auricles in either the second or third stage.

Almost all the features observed in the frog's heart under digitalis may also be found in the mammal, and in addition the latter shows the effects of inhibitory stimulation which are not seen in the frog. The inhibition is the cause of the slow rhythm and block in the earlier phases of digitalis action in the healthy mammalian heart, and the direct action on the conducting fibres can be made out only in the late stages of poisoning; in the frog, on the other hand, the slowing and block arise from the direct action only. In the mammalian heart in extreme malnutrition the reaction resembles that in the frog; the rhythm is slowed and the conduction is impaired through direct action on the cardiac muscle, for it is not prevented by atropine which excludes all inhibitory activity. For example, a mammalian heart perfused for some time with Ringer's solution reacts to digitalis by slowing and block, just as a frog's heart does (Fig. 53). This reaction of the ill-nourished heart to digitalis is of importance, as in the condition in which it is specific in therapeutics there is every reason to believe that the heart is suffering from malnutrition and fatigue.

FIG. 51

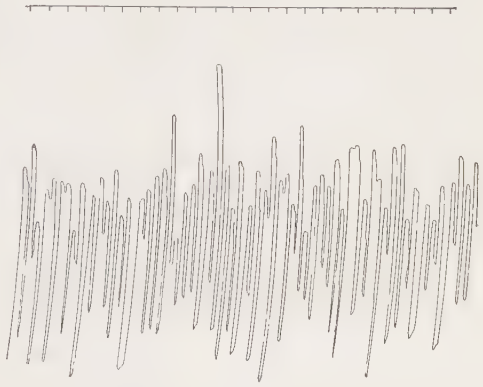


Tracings of auricle (upper) and ventricle (lower) in third stage of digitalis action. Auricle and ventricle each beating regularly but at different rates. The levers move downward in systole, upward in diastole.

Vessels.—Small quantities of digitalis and its allies, such as are used in medicine, have no direct action on the bloodvessels, but larger amounts induce changes in the muscular coat which present some analogy to the changes in the heart muscle. The latter is much more sensitive to the glucosides than the arterial walls however, and an amount of digitalis which is capable of acting on the vessels, proves fatal to the heart in the course of a few minutes. The vascular action has thus no therapeutic importance; it may be

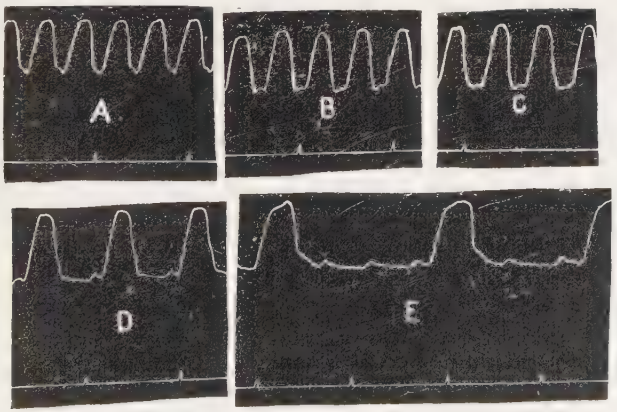
observed by perfusing the surviving vessels with digitalis in Ringer's solution in the frog or mammal. The glucosides vary considerably in their power of contracting the vessels when thus perfused; digitoxin is distinctly more powerful than strophanthin in contracting them. The different vessels also vary in their reaction, those of the intestinal area contracting more readily than those of the kidney, which again appear less susceptible than those of the limbs and brain; the coronary arteries of the heart appear to resemble those of the limbs in contracting when digitoxin is perfused through them, while strophanthin has less effect on their calibre; but therapeutic doses probably have no direct action on the coronaries.

Fig. 52



Tracing of the ventricular movements in the last stage of digitalis poisoning. The lever moves upwards in systole. The characteristic feature is the extreme irregularity, no two contractions resembling each other in form or strength.

Fig. 53



Tracing of the ventricular movements of a rabbit's heart perfused with Ringer's solution containing atropine. *A* and *B*, normal. *C*, after the addition of strophanthin, one part in 500,000, and atropine. The beat is slower. In *D* still greater slowing and block, the ventricle beating once to the auricle's twice. In *E* the auricle was beating four times as fast as the ventricle; the small movements during the pause between the ventricular contractions arose from auricular beats.

The Blood-pressure.—The changes in the heart and vessels are reflected in the blood-pressure, and it is possible that an additional factor may be involved in the action of some of the glucosides on the vasomotor centre.

In man therapeutic doses of digitalis have not been found to cause any appreciable change in the arterial tension; but this statement must be qualified by the addition, that in those cases in which digitalis is most beneficial, the blood-pressure cannot be satisfactorily determined. In animals, however, quantities of digitalis which are sufficient to affect the heart do not increase the blood-pressure appreciably. The increased efficiency of the heart in itself in the first stage would increase the arterial tension, but this appears to be compensated by a slight diminution in the tone of the vasomotor centre, which reduces the resistance in the peripheral vessels and thus permits a freer passage to the blood. In other words, an augmented efficiency of the heart must lead to a rise in blood-pressure if the vessels remain unchanged in calibre, but may lead to an accelerated flow through the tissues if the vessels relax in proportion as the output of the heart increases. Such an acceleration of the circulation has been observed repeatedly under small quantities of digitalis in animals. The reduction in the tone of the vasomotor centre is not due to the glucosides directly, but arises from the increased efficiency of the heart, which supplies a larger amount of blood to the brain and thus reduces the activity of the centre.

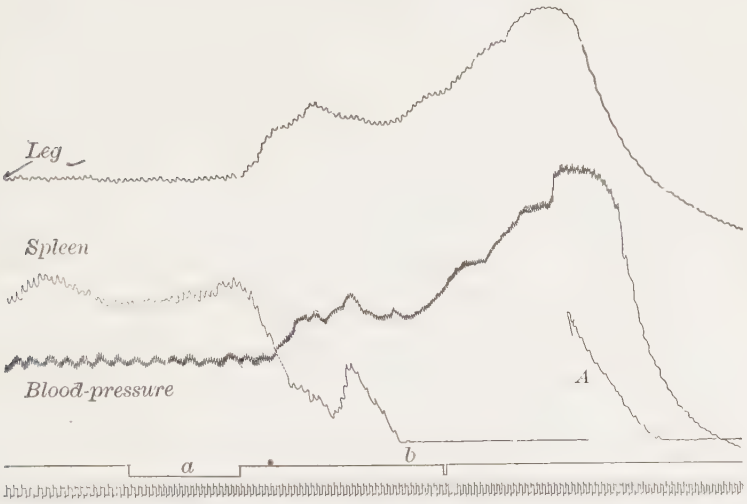
As long as this compensatory action persists in the vasomotor centre, the blood-pressure does not rise from the cardiac action; in man this balance between the heart and the vasomotor centre is more perfect than in the lower mammals owing to the development of the upright posture, and in man changes in the blood-pressure are thus more carefully guarded against and no alteration is caused by digitalis increasing the cardiac output. Further, in cases of heart failure, in which digitalis is prescribed, the vasomotor centre is in a state of unusual activity because the circulation is deficient and the supply to the brain can be maintained only by constriction of the peripheral vessels. As digitalis improves the heart and increases the supply of blood to the brain, the vasomotor centre relaxes its activity, and thus, while maintaining the brain supply, permits more blood to circulate in the other vessels. The blood-pressure does not increase owing to this compensatory factor.

In experiments in animals, a rise in blood-pressure is generally observed under the members of this group, partly because in the lower mammals the balance is less developed than in man and in addition is rendered less active by the anæsthesia, but mainly because much larger quantities are injected in order to induce a rapid effect, such as can be observed in the course of an hour. These larger doses introduce a new factor, however, in the direct action on the vessel walls, which precludes the compensatory activity of the vasomotor centre, and thus the blood-pressure rises, partly from the increased efficiency of the heart and partly from the unusual resistance to the passage of the blood out of the arteries. And this appears to be the final result when digitoxin is injected. But when strophanthin, digitalin, or convallamarin is used, a further complication arises, for these have a somewhat less marked vascular action, and though the vessels of the abdominal organs are contracted in the same way as by digitoxin, those of the extremities dilate. This dilation is partly owing to the increased pressure in the interior overcoming the contraction of the walls,

but is mainly to be ascribed to an imperfect compensatory action of the vasomotor centre. The general result is that the total amount of blood circulating per unit of time is increased but this increase is not uniform in the different organs. Thus both strophanthin and digitalis accelerate the flow through the lungs and through the peripheral muscles (Edmunds), while their effects on the abdominal organs may be to slow the current, to accelerate it, or to leave it unaltered, according to the relative degree of action on the heart and on the vessels.

It follows that in animal experiments the blood tends to accumulate on the arterial side at the expense of the venous, for more blood is pumped into the arteries and it has greater difficulty in escaping. But while under digitoxin the different regions of the body appear to be equally affected, strophanthin, digitalin, and convallamarin not only tend to accumulate the blood on the

FIG. 54



Tracings of the blood-pressure and the volume of the leg and of the spleen of the dog under strophanthus. The volume of the leg increases with the blood-pressure, *i. e.*, the vessels of the leg are dilated; that of the spleen diminishes, *i. e.*, the vessels are contracted; 10 mg. of strophanthin were injected intravenously at *a*, followed by 5 mg. at *b*. (Gottlieb and Magnus.)

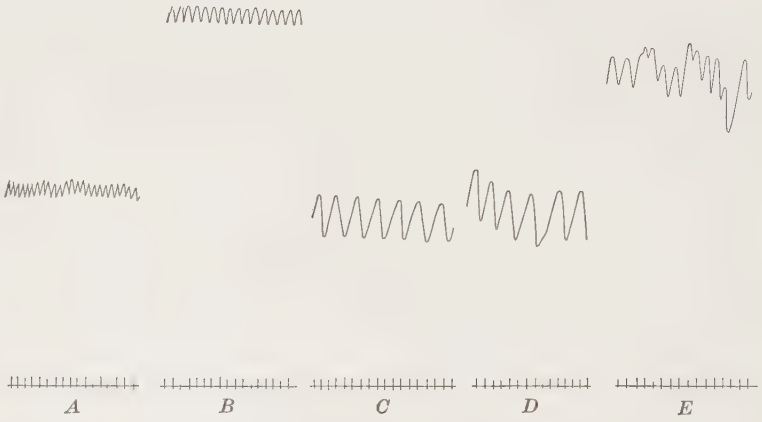
arterial side, but divert it from the internal organs to the limbs. In man, there being no increase in the peripheral resistance, the increased efficiency of the heart must lead to an acceleration of the circulation.

When the extreme slowing of the *second stage* appears in animal experiments, the output of the heart is reduced, and the pressure in the aorta and the velocity of the blood may become subnormal (Fig. 55). When the acceleration of the *third stage* follows, the output is again augmented and the constriction of the vessels is more developed; the blood-pressure rises again but the heart soon becomes irregular in the force of its contractions, the output varies from second to second, and the pressure in the aorta falls slowly. The blood-pressure tracing shows the irregularity of the heart more or less accurately, but must not be taken to indicate at all the real condition of that organ, as the constriction of the arterioles varies at different times Eventually the pressure falls to zero, when the heart ceases.

In experiments on animals with large doses, the pressure in the pulmonary artery is not increased by strophanthin, but rises under digitalis from constriction of the vessels similar to that seen in the systemic circulation. The action on the right heart is similar to that on the left in all particulars.

Action on the **Renal Secretion.**—When digitalis was first introduced to the notice of the medical profession by Withering, its action on the heart was not appreciated. Withering used it only to remove accumulations of fluid from the body, which it accomplished by increasing the secretion of urine. This observation of Withering was soon confirmed by further experience in the use of this drug, but it was long disputed whether this diuretic action occurred in health, or whether it was not confined to cases in which pathological accumulation of fluid were present. Digitalis, however, as is now conceded by almost everyone, causes some increase in the quantity of urine secreted by the normal animal, although this is small compared with that in cases of dropsy. The

FIG. 55



Blood-pressure tracing under digitalis. *A*, normal; *B*, therapeutic stage; *C*, excessive inhibition causing a low blood-pressure from lessened output of the heart. *D*, excessive inhibition with some irregularity in rhythm. *E*, third stage of irregularity, during which the blood-pressure rises again from the increased output of the heart and the further contraction of the vessels.

fluid of the urine is more largely augmented than the solids, though these are also increased. This increase in the urine arises not from a direct action on the kidney, such as is met with under caffeine, but only indirectly through the changes in the circulation; the kidney shares in the general acceleration of the blood-current and functions more vigorously. At the same time the general improvement in the circulation promotes the interchange of blood and lymph, and any accumulation of fluid in the body tends to be reabsorbed into the bloodvessels and then to be got rid of through the kidneys. The diuretic action of digitalis is therefore secondary to the accelerated blood flow and is a result of the changes in the heart alone.[1]

[1] An attempt has been made to explain the diuresis by action on the vessels; it is stated that small doses in animals constrict the vessels of the kidney less than those of the intestine and thus divert more blood to the kidney, while larger ones contract the renal vessels also; but while this may be true in some experiments, diuresis occurs in both animals and man from doses that have no effect on the vessels, and, in fact, quantities sufficient to constrict the vessels are rapidly fatal to the heart.

The Changes in the Circulation in Man can be followed only imperfectly because there is as yet no means of measuring the strength and efficiency of the heart contractions. In many cases no definite alteration in the rhythm follows digitalis treatment even when it is pushed until nausea and vomiting occur. In others, the pulse is distinctly slower, stronger and fuller than before the administration of the drug. It must be added that the strength of the pulse is not to be regarded as a gauge of the changes in the cardiac muscle, for it is due not only to the increased strength of the cardiac contraction, but also to the slow rhythm. When the heart is beating rapidly, the arteries have no time to empty themselves completely and the pulse is small, while on the other hand,

Fig. 56

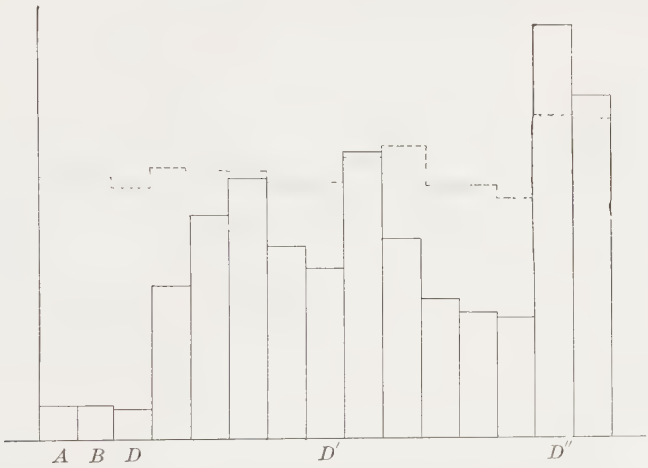


Diagram representing the secretion of urine in a rabbit under digitalis. Each rectangle represents the amount of urine secreted in ten minutes. *A* and *B*, normal secretion. In the next ten minutes a small dose of digitalis, *D*, was injected intravenously and a rapid increase in the secretion followed. At *D'* and *D''*, further injections were made, each being succeeded by a considerably augmented flow of urine. The dotted line represents the average blood-pressure at each period. It will be observed that each injection is followed by some increase in the arterial tension. Contrast Fig. 21 (p. 293) as to the amount of the secretion, and also as to the behavior of the blood-pressure.

when digitalis slows the heart, the arteries have time to empty their contents into the capillaries before the next contraction occurs, the walls therefore become more flaccid, and a new wave of blood causes a more distinct impulse. Irregularities are frequently met in these cases under digitalis, but these will be discussed under the therapeutic uses; in other instances a previously irregular pulse becomes less irregular. In cases in which the pulse remains unchanged in rate, there may be other evidences of the action of the drug, such as an increase in the secretion of urine or relief of dropsy or of dyspnœa. In fever and after hæmorrhage the pulse is especially liable not to show any slowing after digitalis. Electrocardiographic records show that in most cases

the pause between the auricular and ventricular contractions is lengthened, indicating that the conduction is impaired, and some modification of the ventricular wave has also been described (Cohn).

The blood-pressure is not augmented in man to any extent perceptible by the methods in use for measuring it clinically, and in some instances it is distinctly reduced, as has been stated already (p. 420).

In fever the **Temperature** is not infrequently reduced, although it remains unchanged after the administration of digitalis to the normal animal. This action is said by some to be the result of collapse, while others believe it to be due to the changes in the circulation, but neither of these seems to be a very happy explanation. It has been stated already that the members of this series act as stimulants to some parts of the central nervous system, and a possible explanation of their antipyretic action would be an increased activity of the temperature-controlling centres. It has been shown by Harnack that several central nervous stimulants, including picrotoxin, cause a fall in the temperature in this way.

Absorption and Distribution.—The glucosides of this series are peculiarly susceptible to destruction in the alimentary tract, and there is no doubt that a part of those taken by the mouth is rendered inert in the stomach and bowel. After a dose of digitalis leaves, the glucosides may be found in the stomach and upper part of small intestine but none reach the large bowel unchanged. In addition, the absorption is very slow from the alimentary tract; it follows that only a small fraction of the drug administered by the mouth ever reaches the heart. On hypodermic injection, the glucosides cause marked local irritation, and a considerable proportion also seems to undergo decomposition, for much larger quantities are required to induce changes in the heart than are necessary by intravenous application. After the ingestion of large amounts, some glucoside is said to have been found in the liver, but none is detected in the heart or other organs and the blood seems to be free from it soon afterward. Some of the principles have been found in the urine and faces, so both kidney and gut share in the excretion.

Even after they reach the blood the bodies of this series are slow in affecting the heart, while on the other hand their action is very prolonged, the heart only regaining its ordinary rate several days after the drug has been stopped. If the dose be repeated, the action therefore becomes more and more marked (cumulative action) as the glucoside increases in concentration, and a dose which improves the condition at first, may, if continued, lead to the second phase of poisoning. The different glucosides differ in the duration of their action; thus Hatcher estimates that seven-eighths of the strophanthin in the tissues is eliminated within twenty-four hours, while half the principles of digitalis remain active after four days. It is still undetermined what organs or tissues retain the glucosides and which of them are capable of destroying them. Straub has pointed out that the action of strophanthin on the frog's heart is determined by the concentration in which it is applied

and not by the total amount of the glucoside supplied; for example, if 10 drops of a solution circulating through the excised heart are insufficient to bring it to a standstill, 100 drops of the same solution will have no more effect, though 10 drops of a solution of double the strength will arrest it. From this he deduces that strophanthin is not taken up by the muscle by any selective action, but only penetrates the cells in the concentration of the solutions; and in confirmation of this, neither Straub nor others have been able to find the glucoside in the heart muscle, while the fluid remaining in the cavity has lost almost none of its toxic action if applied to a second heart. From the minimal amount of strophanthin which is necessary for action on the heart Straub draws the conclusion that strophanthin acts by changing the membrane of the heart cells, but this cannot be accepted as established. Some others of the series have been found to be taken up in larger quantity by the heart.

Tolerance.—Some species of animals tolerate much larger quantities of the digitalis bodies than others. For example, the snake and toad are not poisoned by amounts which would be fatal to the frog. This arises from the tissues of these tolerant animals not being susceptible to the poisons, and not from any difficulty in absorption or rapidity of excretion; for the isolated hearts in these animals show the same refractory behavior as the intact animal. Among the mammals, the rat's heart has been shown to be much less susceptible to the action of these bodies than the rabbit's. Tolerance has not been shown to be acquired for digitalis and its allies through their prolonged use.

The digitalis bodies weaken and eventually paralyze the **Muscles** and the terminations of the peripheral **Nerves** of the frog. For this purpose it has to be applied in quantities which would at once stop the mammalian heart, and this action certainly never even commences in warm-blooded animals. Large quantities of digitalis act on the unstriated muscle of several organs, such as the stomach and uterus, and increase their movements, and this certainly occurs in excised organs exposed to solutions of the glucosides.

Preparations.

Digitalis (U. S. P.), **Digitalis Folia** (B. P.), foxglove, the leaves of Digitalis purpurea collected from plants of the second year's growth. 0.06 G. (1 gr.); B. P., ½–2 gr. in pill form.

Infusum Digitalis, U. S. P., 4 mils (1 fl. dr.); B. P., 2–4 fl. drs.

Tinctura Digitalis (U. S. P., B. P.), 0.5 mil (8 mins.); B. P., 5–15 mins.

"*Digitaline*" of commerce varies much in composition and in dose, sometimes proving entirely inert, while at other times it has proved poisonous in comparatively small quantities. Crystalline digitaline very often consists largely of digitonin, which is quite devoid of the digitalis action. Other preparations seem to contain much digitoxin. *Digitoxin* has been prescribed in doses of $\frac{1}{2}$ mg. ($\frac{1}{120}$ gr.), but the forms at present on the market vary greatly in strength. *Digalen* is a solution of impure digitalein from the leaves. Dose, 1 mil or 15 mins. *Digipuratum* is said to contain the cardiac glucosides of the leaves in combination with tannin and freed from most of the inactive con-

stituents. Dose, the same as digitalis. Digalen seems to be a very weak preparation and has no advantage over the ordinary tincture. Digipuratum is not superior to the powdered leaf.

The tincture and infusion are the most commonly used preparations. The powdered leaves may be given in the form of pills. The preparations ought to be freshly made, and the infusion and aqueous solutions of the principles must not be kept, as they soon decompose.

Strophanthus (U. S. P.), **Strophanthi Semina** (B. P.), the seeds of Strophanthus Kombé or hispidus, 0.06 G. (1 gr.).

TINCTURA STROPHANTHI (U. S. P., B. P.), 0.5 mil (8 mins.); official dose (B. P.), 2–5 mins.; effective dose, 5–10 mins

STROPHANTHINUM (U. S. P.), the glucoside of Strophanthus Kombé, varies in composition and in power. Dose 0.001 G. ($\frac{1}{60}$ gr.) by the mouth each day or half of this by intravenous injection. Ouabain, or crystalline g-strophanthin from Strophanthus gratus, is also used for intravenous injection in the same dose.

Scilla (U. S. P., B. P.), squills, the bulb of Urginea maritima or Urginea Scilla, cut into thin slices. 0.1 G. ($1\frac{1}{2}$ grs.) in pills.

TINCTURA SCILLÆ (U. S. P., B. P.), 1 mil (15 mins.); B. P., 5–15 mins.

SYRUPUS SCILLÆ (U. S. P., B. P.), 2 mils (30 mins.); (B. P.), 30–60 mins.

SYRUPUS SCILLÆ COMPOSITUS (U. S. P.), containing senega and tartar emetic, 2 mils (30 mins.).

Squills is often prescribed in pill form as a diuretic; as an expectorant the syrup is more often used. The compound syrup, U. S. P., may be ordered instead of a cough mixture, as it contains the chief constituents of such remedies.

The importance of this group in therapeutics is so great that it is to be regretted that no adequate method of chemically estimating the content of active principles is available. For the crude drugs appear to vary in activity and even when the attempt is made to use the glucosides themselves, the difficulty in their isolation and identification leads to uncertainty in their dosage. The U. S. P. recognizes the advisability of assaying the crude preparations biologically, and the active principles may also be standardized in the same way (see p. 44). Only by using these standardized preparations can there be any certainty that the patient is receiving a uniform dose of these drugs (Edmunds).

Methods of Administration.—For ordinary purposes the members of the digitalis group are given by the mouth, and the most suitable preparations are the three tinctures of digitalis, strophanthus, and squills. These are generally given alone in cases of heart disease, and it is of importance to remember that they do not maintain their power if they are kept diluted with water. The tinctures may best be sent out undiluted with directions to take the requisite dose in a wineglass of water. The best results are often obtained from larger doses than the pharmacopœias admit; thus a drachm of tincture of digitalis may be required per day. The tincture of strophanthus is rather stronger than the tincture of digitalis and has a smaller dose. The tincture of squills of both pharmacopœias should be given in twice the pharmacopœial dose to elicit the same effects as the tincture of digitalis. Large doses of these preparations are not always necessary, but there is no question that in many instances the failure of digitalis to relieve symptoms is due to the use of inadequate doses. The action of digitalis, strophanthus, and squills differs very little when they are

given in equivalent doses; tincture of digitalis on the whole is the most reliable.

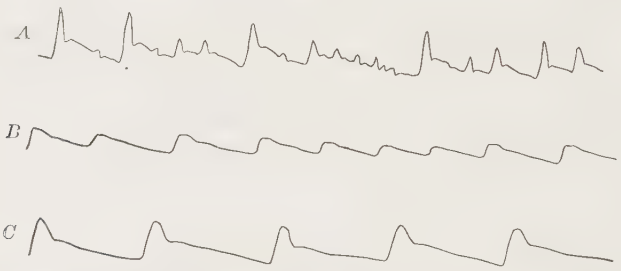
The usual treatment has been to prescribe repeated small doses of the tincture of digitalis, such as 1–1.5 c.c. (15–20 mins.) thrice daily; in this way the beneficial effects are only attained on the second or third day, when enough has accumulated in the tissues. In order to accelerate the action, it is now advised (Eggleston) that one large dose be given, nearly equivalent to the total given in two days by the older method; for example, 8–10 c.c. (2 drs.) of the tincture of digitalis may be given as the initial dose in an adult of average weight, and if no results follow, may be followed by 1 c.c. (15 mins.) thrice daily until the action is elicited. By this method the delay is eliminated and relief may be obtained in twelve hours instead of three days. Whatever method is used, the patient should be under frequent observation, and this is especially necessary after the large initial dose.

The so-called pure principles should not be given by the mouth; strophanthin, the only one of them recognized by the pharmacopœia, undergoes decomposition in the alimentary tract, especially when given in pure form. No preparation can be injected hypodermically in efficient amount owing to the local irritant action, and though intramuscular injections of strophanthin have occasionally been made, they also cause much pain and irritation. In emergencies strophanthin may be injected intravenously in sterilized Ringer's solution. The injection should be made very slowly; not more than 0.5 mg. ($\frac{1}{130}$ gr.) should be given and this is generally dissolved in 2–5 c.c. The injection is not repeated within twenty-four hours except in special conditions and after careful examination of the patient; the treatment may be continued with doses of 1 c.c. (15 mins.) of tincture of digitalis thrice daily, and this may be commenced the day after the injection of strophanthin. The effects of the latter will be passing off when the digitalis begins to act. The lowest dose of digitalis is then found which maintains the improvement and this is continued as long as necessary.

Therapeutic Uses.—Digitalis has long been the sheet-anchor in treatment of diseases of the heart, but little was done to elucidate its clinical action until the last few years (Mackenzie). Much still remains to be investigated, but it has at least been determined that it is much more efficacious in certain forms of cardiac impairment than in others. Its most remarkable therapeutic effects are seen in cases of **Auricular fibrillation**, for which it may be said to be a specific comparable only to quinine in malaria. In auricular fibrillation, the impulses arise in abnormal parts of the auricle and keep that chamber in continual incoördinate activity which prevents its emptying its contents into the ventricle. The multitudinous impulses generated in the auricles descend irregularly to the ventricle, which responds with a rapid beat varying not only in rhythm but also in strength; many of the contractions are too weak to expel any blood into the aorta, while others cause large pulses, and these are intermixed in the most confused fashion; the pulse is thus extremely irregular (Fig. 57). This irregular heart is quite

compatible with moderate health for long periods, but sooner or later the signs of failing circulation appear, the pulse becomes alarmingly rapid, and a dangerous condition develops quickly. If digitalis is now exhibited in full doses, these symptoms of heart failure abate rapidly, improvement beginning after twelve to forty-eight hours according to the method of administration, and the danger disappearing in a few days. If strophanthin ($\frac{1}{130}$ gr.) is injected intravenously, the improvement begins within two hours and is marked in eight to twelve hours. In each case the pulse falls in rate and this slowing proceeds in proportion to the general improvement and may be taken as a measure of it. The heart may be slowed from 130–150 per minute to 50-60 in the course of a few hours, and at the same time the beats become stronger and more equal in size and in time (Fig. 57). The auricles continue to fibrillate after the pulse is slowed, but the ventricle responds to fewer of the impulses emitted by the auricle, because fewer of them reach the ventricle through digitalis lessening the conductivity through the bundle of His.

FIG. 57

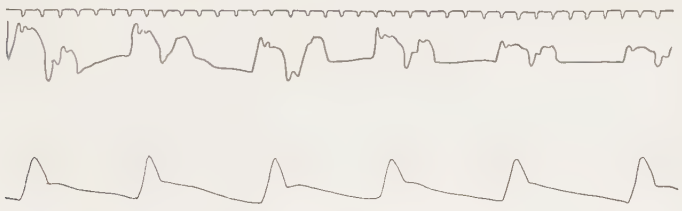


Pulse tracings in a case of auricular fibrillation in man. *A*, before treatment; *B*, after six days' treatment with tincture of digitalis (60 mins. each day); the pulse is slower (62 beats per minute) and more regular. *C*, after ten days' treatment; pulse, 41 per minute, regular (spontaneous ventricular rhythm). (Windle.)

The slowing of the pulse in auricular fibrillation does not arise from inhibitory action, for it is not prevented by atropine; in fact when a patient is under digitalis and the pulse is slowed, the inhibitory mechanism is less active than before treatment when the pulse was rapid; this is shown by the fact that paralysis of the inhibition by atropine does not accelerate the heart so much under digitalis in these cases as it did before treatment was begun. The specific effect of digitalis and its allies in auricular fibrillation must therefore arise from the direct action of the drug on the cardiac muscle. Auricular fibrillation can be induced experimentally in animals by electrical stimulation of the auricle, and when this is done in a healthy heart the digitalis action on muscle does not render the ventricular beat slow and regular as it does in auricular fibrillation in man. But if this condition is induced in a perfused, badly nourished heart, digitalis slows the ventricle and makes it regular exactly as in clinical cases. The therapeutic action of digitalis in auricular fibrillation is thus due to the specific muscular

action on conduction, which is seen typically in the frog and in the mammalian heart in malnutrition (p. 418). When clinical auricular fibrillation is not attended by grave malnutrition, digitalis does not slow the pulse materially, while in some conditions in which the heart is feeble but no fibrillation is present, slowing is induced. The special action in auricular fibrillation thus arises from the extreme malnutrition of the heart which often occurs in this condition. The blood-pressure cannot be accurately estimated in auricular fibrillation owing to the irregularity of the pulse, and it is therefore unknown whether it is altered under treatment; Stewart found the rate of the blood flow through the hand distinctly increased in these cases when treated with digitalis, that is the condition of the heart and its output both improved while the pulse rate fell.

FIG. 58



Tracing of the radial pulse (below) and of the heart-apex (above) in a case of auricular fibrillation treated with digitalis tincture. The apex tracing shows coupled beats (bigeminus), each normal contraction being followed by a rapid secondary beat; these secondary beats are not strong enough to expel blood into the aorta and are not indicated on the radial tracing. (Windle.)

Not infrequently in this condition the dose has to be very large, and if it be continued the patient suffers from nausea and vomiting. Or the pulse may fall to about 40 per minute (Fig. 57) and become regular; the ventricle now receives no impulses from the auricle, but has developed its own spontaneous regular rhythm. More frequently the heart develops the bigeminus form shown in Fig. 58, in which each full beat is followed very quickly by a secondary one; here the large contractions arise from auricular impulses, but the excitability of the ventricle has risen to a point at which it also discharges impulses, and this coupled rhythm is the result. These are all indications that the drug has been pushed too far, and they all disappear when the dose is reduced.

In some cases of auricular fibrillation in which the heart is not much accelerated, digitalis has no such striking effect though improvement occurs under it. And even when digitalis relieves the symptoms of heart failure in auricular fibrillation, it does not arrest the underlying process and the auricle continues to beat in its previous irregular way. Digitalis only prevents the ventricle from being exhausted, by limiting the number of impulses which descend from the auricle. On the other hand, the quinine alkaloids will be shown to arrest the irregular beating of the auricle and restore it to a condition of sanity (p. 469).

Another condition in which digitalis treatment is equally successful is **Auricular flutter**, in which the auricle is again the seat of abnormal excitation and beats at a very high rate but quite regularly. The ventricle is also regular though very rapid and responds to only half of the impulses descending from the auricle; the rapid rhythm of the ventricle tends to exhaust it and calls for treatment. Digitalis given in full doses 4–5 c.c. (1 dr.) a day changes the regular flutter to fibrillation and at the same time reduces the conductivity of the His bundle, so that the beat of the ventricle becomes very slow, sometimes only 30–40 beats a minute. On now stopping the treatment, both flutter and fibrillation are found to have ceased and the heart beats in normal rhythm. The explanation seems to be that digitalis, either through its vagus or its muscular, action further excites the auricle and changes the flutter to fibrillation; but fibrillation of recent development tends to revert to normal rhythm and when the digitalis action passes off, the flutter does not return but the normal pacemaker resumes its sway. The treatment of flutter with digitalis not only abates the symptoms but actually cures the condition from which they arise, thus contrasting with the results obtained from it in fibrillation and resembling those following the use of quinidine (p. 476).

In **Other Forms of Heart Disease** the effects of digitalis are less spectacular and although improvement undoubtedly results from the treatment, there is no such guide as is offered by the slowing of the pulse in fibrillation. It is therefore not always easy to determine how far the improvement is to be attributed to the digitalis and how far to such auxiliaries as rest and general treatment. Such measurable symptoms are often presented as dropsy, however, and the fall in weight from diuresis under digitalis is as significant evidence as the fall in pulse rate in fibrillation. Few accurate observations are as yet available except in auricular fibrillation, but they suffice to show that the beneficial action of digitalis is not confined to this special form of heart disease. In general terms it may be said that improvement is seen in a large number of conditions in which the efficiency of the heart is impaired and the blood is no longer pumped from the venous reservoirs to the arteries in adequate amount. The deficient circulation no longer suffices to maintain the nutrition of the tissues, including the heart, and dilatation of the heart chambers, congestion of the lungs, œdema and dropsy follow; the kidneys and other organs become overfilled with venous blood and the whole economy is thrown into disorder. The treatment obviously comprises rest to relieve the strained organs, along with some member of this series to increase the strength of the contractions of the heart and thus to compensate for the disorders which are the primary cause of the condition. And under digitalis such improvement occurs; the congestion disappears, the kidneys secrete more rapidly and drain off the accumulations of fluid in the tissues and cavities of the body. The heart itself is better nourished through the acceleration of the bloodstream, and is now able to hypertrophy in order to meet the strain thrown upon it by such damages as destruction of the valves. The only action of the drug which seems to be necessary for this purpose is its power to increase the strength

of the contraction; how far the contractions are actually strengthened in these cases cannot be determined, as no method is known by which this can be measured. It is possible that the dilatation of the heart may be reduced by the muscular action, as occurs in animal experiments, but here again it is difficult to measure the improvement in man. But if such an effect follows either from the direct action of the drug or as a result of the improved nutrition, it may tend to compensate for the imperfection of a diseased valve by narrowing the orifice during diastole. And as the auricle is improved by digitalis, it may empty itself more completely into the ventricle and perhaps relieve the venous stasis in this way. The improvement in these cases is thus readily intelligible, but further observation is required before the details of the action can be established. In some of these patients digitalis slows the pulse, but this is not an essential factor, for the improvement is not more rapid than in similar instances in which no such change occurs.

The beneficial action of digitalis is generally stated to be more obvious in disease of the mitral than in that of the aortic valves. This view may have arisen from the fact that auricular fibrillation is often accompanied by mitral disease. In some cases of aortic valve failure digitalis appears to be of value, but there seems some reason to doubt whether it is as often efficacious as in mitral disease even when the fibrillation cases are excluded. It is sometimes stated that in aortic regurgitation digitalis is dangerous owing to its prolonging the diastolic interval and thus allowing more time for the blood to flow back from the aorta. In many cases, however, the heart is not slowed and there is thus no prolongation of the diastole; and it seems unlikely that even when slowing occurs it is sufficient to counterbalance the benefits of the stronger contraction in systole. In experimental lesions of the aortic valves in animals, digitalis is found to improve the efficiency of the heart and a smaller mortality occurs in animals under treatment than in the controls.

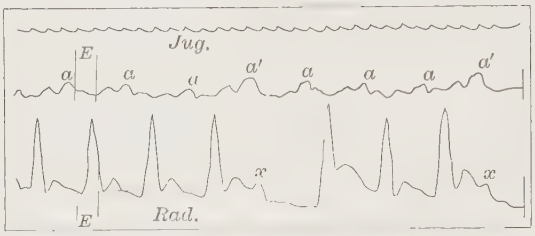
On the right side of the heart the same action occurs as on the left, and in dilatation of the right heart, such as occurs in some pulmonary diseases, digitalis and its allies are beneficial, apparently by increasing the strength of the ventricular contraction.

In the majority of these non-fibrillating cases the pulse is not slowed more than can be accounted for by the rest and general treatment. In a certain proportion, however, distinct slowing is observed as the heart comes under the influence of the drug, or the pause between the contractions of the auricle and ventricle is lengthened; and, as this generally disappears under atropine, it is obviously inhibitory in character in most cases and thus different from the slowing seen under digitalis in auricular fibrillation. Cohn states that the T-wave in the electrocardiogram shows alterations from direct action on the heart muscle.

As regards the irregularities in these non-fibrillating cases, there is no reason to believe that digitalis has any direct action on them, though they may disappear in the course of treatment as the result of the improved nutrition of the heart.

On the other hand, the use of digitalis sometimes gives rise to irregularities, and the character of these has received a good deal of attention of late years, The first form arises from the muscular action, which may increase the excitability of the ventricle or auricle so much that spontaneous beats (extrasystoles) arise (Fig. 59). These are not of

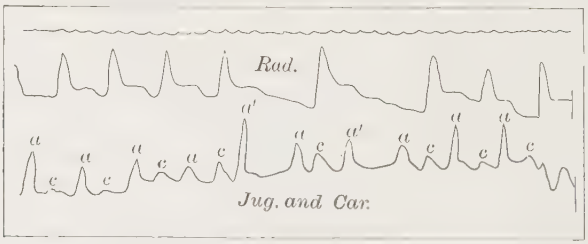
Fig. 59



The lowest tracing is given by the radial artery, the next by the jugular vein, while the time is given in one-fifth seconds above. In the jugular tracing *a*, *a'*, indicate the auricular contractions. In the radial tracing, the large beats are the normal pulse waves; at *x*, a premature, weak contraction of the ventricle occurs (extrasystole), arising from the increased spontaneous irritability of that chamber induced by digitalis. The larger size of *a'* is due to the fact that when the auricle contracts the ventricle is already in systole, and therefore cannot receive the auricular contents, which are thus sent back into the veins, producing this larger wave. (Mackenzie.)

great importance, but the heart should be carefully watched and, if possible, the dose should be reduced. Other forms arise from the stimulation of the inhibitory mechanism, which, as has been stated, occurs in a certain proportion of patients and which may become very marked. This vagus stimulation merely slows the heart in the milder

Fig. 60

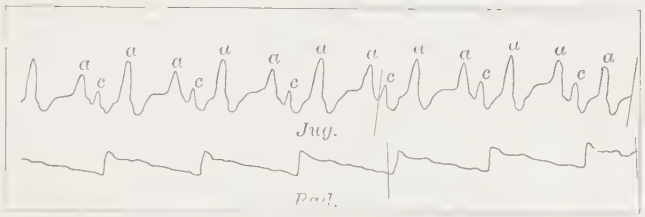


Tracings from the radial artery and the jugular vein in a case of heart-disease treated with digitalis in large doses. The waves *a*, *a'* on the jugular tracing indicate the auricular contractions and are seen to be perfectly regular in rhythm throughout; the auricle is, therefore, beating regularly. The radial pulse intermits at intervals, showing that the ventricle has not responded to the impulses which in the auricle gave rise to the contractions indicated by *a'*. (Mackenzie.)

forms, the beats remaining regular. Or the slowing which occurs in normal people in correspondence with the breathing, may be exaggerated, and the slow, powerful contractions cause an unpleasant sensation in the chest. This occurs when the vagus is strongly stimulated from any cause and is not peculiar to digitalis. When this form of irregularity

sets in, the dose should be reduced or the drug omitted altogether for a few days. Not infrequently, a less obvious vagus effect causes irregularity under digitalis; the passage of impulses from the auricle to the ventricle is retarded or entirely arrested, from the conduction through the connecting fibres being reduced. Before the treatment the fibres were able to conduct all the impulses from the auricle to the ventricle. But now an occasional impulse fails to pass, or perhaps only one of two impulses passes to the ventricle. When an impulse fails to reach it,

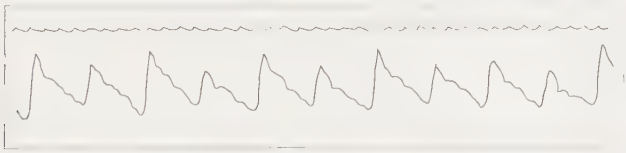
FIG. 61



Slowing of the pulse due to digitalis depressing conductivity, so that the ventricle fails to respond to every second stimulus from the auricle. While the ventricle contracted forty-eight times per minute, the auricle contracted ninety-six times. (Mackenzie.)

the ventricle remains in diastole (dropped beat) (Fig. 60), and when only one-half of the impulses pass to it, the rhythm of the ventricle is only half that of the auricle (half-rhythm) (Fig. 61). Or the block may be complete, no impulses passing through the fibres at all, and in this case the ventricle takes up its own spontaneous rhythm (heart-block). Another form of block may occur between the sinus and the auricle (sino-auricular block), and both auricle and ventricle now intermit a contraction at variable intervals. In all these forms digitalis interferes with the passage of impulses from the auricle to the ventricle, or from

FIG. 62



Typical *pulsus alternans* due to digitalis. Each pulse period is of the same duration while the size of the beat varies rhythmically. (Mackenzie.)

the sinus to the auricle, by stimulating the inhibitory mechanism, which lessens the conductivity of the connecting fibres. The irregularity therefore disappears under atropine which paralyzes the inhibitory mechanism. But in rarer cases the digitalis heart-block does not arise from the inhibitory stimulation but from direct action on the conducting fibres, and this form of block which may be sino-auricular or auriculo-ventricular, is not relieved by atropine. The inhibitory block under digitalis is similar to that seen in experiments on mammals in the second

stage, while the rarer block from direct action is the same as that seen in the frog, in the ill-nourished mammalian heart, and in the human heart in auricular fibrillation. When heart-block occurs under digitalis, the treatment should be abandoned or the dose reduced. Slight slowing in non-fibrillating cases does not indicate a change of treatment. Another form of irregularity which sometimes appears under digitalis is known as *pulsus alternans* (Fig. 62), and is marked by an alternation of strong and weak beats of the radial pulse. This generally indicates impaired contractility of the ventricular wall, and its occurrence under digitalis has not as yet received adequate explanation.

In numerous **Acute Febrile Conditions** the heart becomes affected, possibly in part by the high temperature, but largely from the toxic products circulating in the blood. The chief cardiac symptoms are dilatation with a weak systole and a small "fluttering" pulse. In these cases digitalis and other similar drugs may be of service in slowing the accelerated heart and in increasing the extent of systole, and thus improving the general circulation. In pneumonia more especially, improvement is often seen after digitalis. In this disease, besides the toxic action on the heart, there may be present more or less obstruction of the pulmonary vessels through pressure, resulting in overwork and dilatation of the right heart. The routine treatment of pneumonia with digitalis is often recommended, but is to be deprecated on the general principle that a drug is not to be prescribed until some special indication for it appears; unless distinct evidence of circulatory disturbance is present, digitalis ought to be withheld.

In acute fevers the inhibitory mechanism is often less irritable than normally, and the activity of the drug must not be estimated by the slowness of the pulse.

In some affections of the heart, such as very extensive fibrous or fatty degeneration, digitalis often is of little or no service, and some authorities deprecate its use, chiefly on the erroneous view that it may raise the blood-pressure and increase the resistance against which the heart has to work. In the light of recent work this argument falls to the ground and the general view may be stated that while digitalis may fail to improve these cases, it has no deleterious effect on them. In other cases, while the condition of the heart is eminently suitable for digitalis treatment, disease of other parts of the body, such as extensive arterial degeneration, is said to preclude its use on account of the danger of rupture of the arterial walls. And many substitute strophanthus for it in these cases in the belief that there is then less risk of the blood-pressure rising to a dangerous height. But as a matter of fact there is no reason to anticipate any extensive rise of blood-pressure under either digitalis or strophanthus, and the apprehension is thus groundless. The same may be said of the supposed danger of digitalis in the high blood-pressure of renal and arterial disease. A high blood-pressure ought not to be regarded as definitely contra-indicating the use of digitalis or its allies, for excellent results often follow its exhibition in these cases, provided the special indications for digitalis are presented in venous

stasis, œdema, or deficient urine. In these cases the high pressure presumably arises from excessive activity of the vaso-constrictor centre inducing mesenteric constriction in an attempt to maintain the blood supply to the brain; this involves an abnormal resistance to the circulation and imperfect nutrition of various organs. Digitalis by increasing the efficiency of the heart improves the blood supply of the brain, and the activity of the vaso-constructor centre is abated, leading to a more normal state of the circulation and often to a lower arterial tension.

Valvular disease is not in itself an indication for digitalis, for the heart tends to undergo compensatory hypertrophy in favorable conditions without the use of any drug whatever, and digitalis is indicated only when no such compensation occurs. At the same time hypertrophy of the heart is not a contra-indication, as is often stated, for a special strain may cause excessive dilatation in a hypertrophied heart, and digitalis may be necessary until a second hypertrophy has occurred and restored the equilibrium once more.

The diuretic action of digitalis is not advised except where other indications than a diminution of the renal secretion are present, for in ordinary cases it has much less effect than caffeine and other diuretics. If the anuria be secondary to disturbances of the circulation, however, digitalis is the diuretic par excellence and cannot be replaced by any of the ordinary means of promoting the urinary secretion, although they may advantageously be combined with it. Squills and digitalis are often prescribed together, where large accumulations of fluid have to be removed. A famous pill used in these cases contains a grain each of digitalis, squills, and calomel.

Several of these drugs are of considerable benefit in pulmonary diseases accompanied by cough. Thus in bronchitis, more especially in cases of old standing, the addition of squills to an "expectorant mixture" is often followed by the most satisfactory results. The action here is probably twofold. In the first place, the right heart may be dilated owing to the frequent strain put on it by coughing, and squills remedies this condition by its usual cardiac action. In the second place, all these drugs possess to a certain extent emetic properties, and thus cause an increase in the bronchial secretion, and render the sputum less tenacious and more easily expectorated. The addition of squills has the same effect as the prescription of ipecacuanha, along with the further action on the heart.

Digitalis is sometimes prescribed to stop hæmorrhages on the erroneous view that it constricts the vessels; even if this were correct, the flow through them would not necessarily be limited, but it is now known that quantities sufficient to narrow the vessels are fatal to the heart.

Cumulative Action—Digitalis is often given in insufficient amount from a dread that it may cause serious results through its cumulative action. This apprehension does not seem to exist so much in regard to strophanthus and squills, though these also induce cumulative effects when they are given in sufficient doses. As a general rule no effects are noted for one or two days after the exhibition of drugs of this series in

moderate doses. Improvement then begins if the case is suitable and the dose adequate, and steady progress may be made for some time. Then the symptoms of excessive action may set in suddenly—the pulse becomes alarmingly slow and irregular, the patient complains of weakness and faintness, nausea, and occasionally vomiting. This is known as the cumulative action, and is due to the slowness with which the drug is excreted or destroyed. The absorption of the drug given by the mouth is slow, but it is held in the tissues in some form of combination and thus the concentration tends to increase with each successive dose; this slow elimination is shown by the action continuing for several days after the treatment has been discontinued. As the drug accumulates in the tissues the beneficial action is slowly developed, but if the treatment is continued, a higher concentration is reached and finally becomes equal to that induced by a single poisonous dose and the corresponding symptoms follow. The fear of this condition is much exaggerated, for the symptoms disappear in a few hours if the drug is omitted. And they may generally be avoided altogether if a close watch is kept on the pulse, and the dose is reduced as soon as it becomes very slow or at the first appearance of headache, nausea, or loss of appetite. All of the digitalis series hitherto examined prove to be cumulative in their action, but some of them, notably digitoxin, are more dangerous than others. In fact, according to Fraenkel, digitoxin can only be used safely in doses which induce no changes in the pulse for several days, for if the pulse be slowed by a single dose, its repetition within twenty-four hours induces severe poisoning. The symptoms of cumulative action under digitalis, strophanthus, and squills are very similar; there is perhaps more tendency to diarrhœa under the two last than under digitalis.

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XXII. ACONITINE AND VERATRINE.

This series embraces a number of alkaloids, which resemble each other closely in their chemical and pharmacological properties. Some of them which were formerly believed to be distinct are now said to be identical, and it is not improbable that future investigation will still further reduce the numbers of the group.

These alkaloids are found in a number of species of the Aconitum genus, the best known of which are Aconitum Napellus, containing *Aconitine* ($C_{34}H_{45}NO_{11}$) Aconitum ferox, *Pseudaconitine* ($C_{36}H_{51}NO_{12}$), and Aconitum Japonicum, *Japaconitine* ($C_{34}H_{49}NO_{11}$).

When aqueous solutions of these alkaloids are heated, they are broken up into one or more acids and simpler bases; aconitine forms acetic and benzoic acids and *Aconine*, so that aconitine is acetyl-benzoyl-aconine. Pseudaconitine forms *Pseudaconine*, and Japaconitine *Japaconine* in the same way. These decomposition products are found in the plant and in the ordinary preparations, so that their toxicity varies very considerably.

Another alkaloid which resembles aconitine closely in its pharmacological action, but which is less known, is *Delphinine*. It is found in stavesacre (Delphinium Staphisagria), along with a number of other bases, which may be the products of its decomposition.

The symptoms caused by aconitine, pseudaconitine, japaconitine, and delphinine are very similar, differing mainly in degree and not in kind. Pseudaconitine is more poisonous than japaconitine which in turn is slightly more active than aconitine. Delphinine is much less poisonous.

Symptoms.—After very large quantities of aconitine death may result instantaneously, apparently from simultaneous failure of the heart and central nervous system.

If smaller quantities be swallowed, there is noted, after the ordinary bitter taste of the alkaloid, a feeling of warmth in the mouth and throat, which agreeable at first, soon becomes prickling and tingling, and extends to the stomach and eventually to the skin. This is accompanied by a profuse flow of saliva and often by vomiting. The pulse is very slow and may be irregular, and later becomes weak and imperceptible, when symptoms of collapse appear. The respiration is slow and labored, and great muscular weakness is complained of. After a time the smarting and tingling of the skin are no longer felt, and on examination the cutaneous sensibility is found to be much reduced. The intelligence remains unimpaired to the last in many cases, although unconsciousness sometimes occurs, and death is generally, but not invariably, preceded by convulsions. The pupil is unaffected except when convulsions supervene, when it is dilated. The prickling of the throat and skin is the most characteristic symptom, and is practically diagnostic in cases of poisoning, no other drug excepting veratrine having this effect. Death is sometimes due to paralysis of the respiratory centre from the direct action of the poison, but in other cases the heart fails before the respiration.

In small doses aconitine induces tingling of the lips, tongue and throat, which is followed by some nausea and a feeling of weakness and depression. The heart is generally accelerated from the nausea.

Action.—The prickling, tingling sensation is due to an affection of the **Terminal Organs of the Sensory Nerves,** as is shown by its appearing first at the point of

application of the drug. Thus, when aconitine is swallowed, the prickling and warmth is felt in the lips, tongue and throat, and after small doses may be confined to these parts, while if an ointment containing aconitine be rubbed on the skin, the same sensation is induced locally. But no redness or swelling of the skin is induced, nor are blisters formed, so that aconitine differs entirely from the class of skin irritants (page 76). It evidently acts by stimulating the terminations of the sensory nerves, more especially those of common sensation, while the other sensory end organs have not been shown to be involved. Thus, apart from the bitter taste which it possesses in common with all alkaloids, aconitine has no effect upon the taste organs during this stage. The stimulation afterward passes into depression, which induces a sense of numbness at the point of application, and in cases of poisoning, in all the surfaces of the body. The taste nerves seem to be involved in this effect, if Laborde's statement be correct that sweet substances have no taste after aconitine. The irritation of the sensory terminations often causes a number of reflexes, such as sneezing, coughing, increased secretion of saliva, and vomiting, although some of these may be due in part to stimulation of the medullary centres. Evidence of the stimulation of **Other Terminations** is presented in fibrillary twitching of the muscles in the frog and sometimes in mammals. This is prevented by curara, but not by section of the nerves, and is therefore attributed to stimulation of the terminations of the motor nerves in muscles.

Circulation.—The effects of aconitine on the circulation have given rise to some misunderstanding owing to their complexity. After small quantities, the heart does not seem to be affected in man, while in maximal therapeutic amounts it is very often accelerated through the nausea induced by the irritant effect in the stomach. In cases of poisoning the heart is stated to be very slow and irregular, and this can easily be elicited in anæsthetized animals by the injection of aconitine intravenously. This slowing is due to stimulation of the inhibitory centre in the medulla, and is absent in experiments in which the vagus nerves have been divided previously to the injection or in which atropine has paralyzed the inhibitory terminations in the heart.

In large doses aconitine exerts a further, direct action on the heart, which suddenly accelerates from the slow vagus rhythm to one far above the normal. Soon irregularities follow of many different forms, one of the most common being reversal of the beat, in which the ventricle contracts before the auricle and gives the rhythm to the heart. Other arrhythmias also are attributable to the same increase in the excitability of the heart muscle, which is manifested in numerous extrasystoles in the auricle and ventricle, or in groups of rapid rhythm arising from one or other chamber and alternating with periods of fairly regular rhythm. The conduction power of the heart muscle is lessened and this leads to intermissions of the ventricle or auricle. And changes occur in the contractility, so that *pulsus alternans* often appears. All of these effects may be elicited at the same time, giving an extremely complicated tracing. Finally the ventricle passes into fibrillation and the circulation ceases. These changes arise from direct action on the heart muscle, but there is no reason to suppose that it is affected by therapeutic doses. After section or paralysis of the vagus, a much larger quantity of aconitine is required to produce the acceleration and final delirium than when the nerves are intact. The frog's heart is affected by aconitine in the same way as the mammal's and presents the same diversity in rhythm.

The blood-pressure in mammals falls rapidly from the lessened output of the heart in the stage of vagus stimulation. After the stage of acceleration has set in, the blood-pressure becomes extremely irregular, alternately sinking to zero and remaining at that point for some seconds and again attaining a fair height. The vasomotor centre seems eventually to become paralyzed, while the vasomotor nerves and their terminations in the periphery remain unaffected.

The **Respiration** is early affected in aconitine poisoning; it becomes much slower, the movements are labored, and the animal suffers from marked dyspnœa. In fatal cases the respiration soon becomes interrupted by convulsions,

and in the intervals between these becomes weaker and eventually ceases. The action appears to be a direct one on the respiratory centre, which is paralyzed before the heart begins to fibrillate as a general rule, but sometimes continues to act for a few seconds later.

Central Nervous System.—The higher centres seem to be almost unaffected by the drug, for consciousness has often remained to the end, and when this is not the case, the mental symptoms are to be ascribed to the changes in the heart and respiration. The muscular weakness and depression felt after small quantities appear to arise from the nausea and not from any direct nervous action. Some of the lower centres in the medulla oblongata are directly affected; thus the centres for inhibition of the heart, for vasoconstriction and for vomiting are all excited by large amounts though therapeutic doses have no effect on them. The respiratory centre on the other hand is depressed and finally paralyzed, while the rest of the central nervous system is shown to be still irritable by the occurrence of convulsions.

The peripheral nerve trunks are paralyzed by the application of aconitine to them and this is said to occur in the frog when aconitine is injected hypodermically. The muscles do not respond to aconitine except in much higher concentration.

The **Secretion** of saliva is greatly increased by aconitine from the irritation of the sensory terminations in the mouth and from the nausea. The cold perspiration observed in poisoning may be ascribed to the collapse rather than to any direct action on the sweat glands, although Aubert states that aconitine is a powerful diaphoretic in itself.

Aconitine sometimes reduces the **Temperature** both in fever and in normal animals, but the precise way in which this action is elicited is unknown. Brunton and Cash found that after aconite the temperature fell more rapidly than usual if the animal was kept in a cool bath, but rose more readily if it was subjected to external warmth; this observation would seem to indicate that aconite renders the temperature centres less sensitive.

In cases of **Poisoning** in animals, atropine has been found to alleviate the symptoms and not infrequently to lead to recovery after doses which would otherwise have been fatal.

Aconitine is **Excreted** mainly by the urine. Minute quantities have also been found in the saliva and bile.

Benzaconine is much less poisonous than aconitine and, in fact, can scarcely be included among active poisons, though large quantities act on the heart, slowing it and rendering it irregular, and also depress the respiration. It has no effect on the sensory terminations. **Aconine** itself is almost inactive, but large quantities strengthen the heart beat and paralyze the terminations of the motor nerves like curara. It seems unlikely that these alkaloids have any influence on the action of the aconite preparations, although the possibility cannot be excluded at present.

The alkaloids obtained from some other species of Aconitum have been found to differ considerably from aconitine and pseudaconitine in their action. In Aconitum septentrionale three bases *lappaconitine*, *septentrionaline*, and *cynoctonine* have been discovered. Lappaconitine causes clonic convulsions, vomiting, dyspnœa and finally paralysis of the respiration and heart, and in the frog lessens the sensibility of the skin. Septentrionaline does not cause poisoning when taken internally, but injected subcutaneously induces local anæsthesia and later paralysis of the motor terminations like curara. Cynoctonine is also inactive when swallowed and is less poisonous than the others when applied by hypodermic injection, when it causes tonic and clonic convulsions which are not generally followed by paralysis. Two alkaloids, *lycaconitine* and *myoctonine*, have been found in Aconitum lycoctonum, and induce almost identical symptoms. They increase the reflex excitability, and this is followed by convulsions and later by paralysis of the terminations of the motor nerves and by failure of the heart.

Preparations.

The aconite preparations of the U. S. P. may be standardized by the biological assay method (p. 45).

Aconitum (U. S. P.), **Aconiti Radix** (B. P.), the root of Aconitum Napellus, Monk's-hood, containing 0.5 (0.4 B. P.) per cent. of aconitine.

Tinctura Aconiti (U. S. P.), 0.045 per cent.; dose, 0.3 mil (5 mins.).

Tinctura Aconiti (B. P.), 0.04 per cent.; 2–5 mins.

Therapeutic Uses.—Aconite is employed to some extent to slow the pulse and reduce the temperature in fever. Accurate observations show that it has no effect in slowing the pulse when given in therapeutic doses, and its action on the temperature is very uncertain. It has, therefore, been replaced by the newer and more powerful group of antipyretics for this purpose.

The action of aconitine on the sensory nerve terminations suggested its local use in cases of neuralgia, and there is some evidence that its application relieves this condition, though it cannot be said to be beyond question. Either the tincture, or a 2 per cent. solution of the alkaloid in oil may be employed externally. Aconitine has also been injected subcutaneously ($\frac{1}{100}$–$\frac{1}{50}$ mg.) in neuralgia, but this mode of application is not to be recommended, as it causes very severe pain, which in some cases lasts a long time. Aconitine is the most poisonous of the alkaloids, 0.2 mg. ($\frac{1}{300}$ gr.) taken by the mouth inducing distinct symptoms in man, and its use must be guarded. The internal administration of aconite in neuralgia does not seem to be followed by any improvement. Staves-acre is scarcely used in medicine at present.

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Veratrine.

A number of alkaloids have been found in species of Veratrum and allied genera, and resemble aconitine in their pharmacological action. *Veratrine* is found in the seeds of Schœnocaulon officinale or Asagræa officinalis (sabadilla or cevadilla seeds) and also in Veratrum sabadilla and Veratrum viride or Green Hellebore.[1] It is a mixture of two alkaloids, *cevadine* and *veratridine*. The chief alkaloid of Veratrum album, White Hellebore, is *protoveratrine*. Alkaloids of this series have been found in several species of Zygadenus, the Death Camas, which is an important cattle poison in the Western United States.

Each of these alkaloids is accompanied by a number of others, most of which are imperfectly investigated chemically and pharmacologically. In cevadilla, in addition to *Veratrine*, there are found *Cevadilline*, *Sabadine*, *Sabadinine*, and *Sabatrine*. In white hellebore, *Protoveratrine* is accompanied by *Jervine*, *Pseudojervine*, *Rubijervine*, *Protoveratridine*, and others. Green hellebore contains *Cevadine*, *Jervine*, *Pseudojervine* and *Veratridine*. Jervine, Sabadine, and Sabadinine are known to possess some action on the organism; Cevadilline has not been examined, while the others are said to be inactive.

[1] Hellebore is also the popular name of Helleborus niger, which differs entirely from Veratrum in its principles and also in its action.

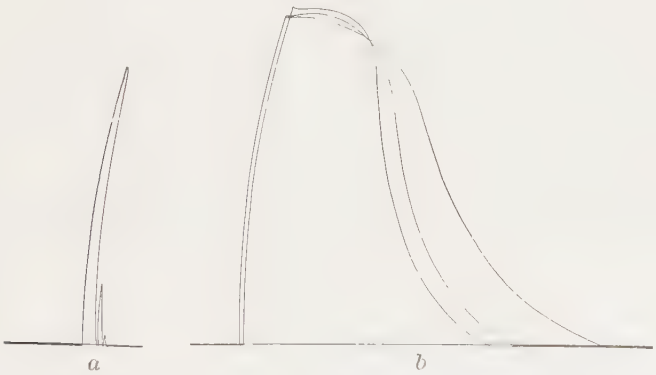
Cevadine ($C_{32}H_{49}NO_9$), veratridine ($C_{37}H_{53}NO_{11}$) and protoveratrine ($C_{32}H_{51}NO_{11}$) are powerful alkaloids, the last almost rivaling aconitine in its toxicity. Like aconitine, each of these may be decomposed into a base and an acid, cevadine forming angelic acid and cevine, while protoveratrine forms isobutyric acid and a similar base.

The effects of veratrine resemble those of aconitine very closely in their general character and particularly in regard to the sensory terminations; but the muscles present a curious reaction to veratrine, which is entirely absent in aconitine poisoning.

Symptoms.—The symptoms differ from those of aconitine only in the greater tendency to colic and purging under veratrine, and in the presence of fibrillary twitching of the muscles and convulsions in the later stages of poisoning.

Action.—The prickling of the skin is a striking feature of veratrine poisoning and the same action leads to violent sneezing and coughing when small quantities of veratrine come in contract with the sensitive mucous membranes of the nose and throat. After the irritant action has lasted for some time, the sensory terminations in the skin become less sensitive, and a feeling of numbness and cold is noted. Protoveratrine seems to cause less irritation of the sensory terminations than veratrine, and the subsequent local anæsthesia is more complete.

Fig. 63



Tracings of muscular contractions from the gastrocnemius of the frog. *a*, normal; *b*, three successive contractions taken at intervals of one minute, five minutes after the injection of veratrine. The contraction is higher and much more prolonged than in *a*, and the lever returns very slowly to the base line.

The most characteristic action of veratrine is that on the **Striated Muscles.** If a small quantity be injected into the lymph-sac of a frog a curious clumsiness and awkwardness in the movements becomes apparent, and after a few minutes it is evident that this is due to inability to relax its muscles. When a muscle is exposed, it is seen to contract as rapidly as usual, but instead of immediately relaxing again, it remains shortened and offers resistance to the contraction of the opposing muscles. The animal can no longer coördinate its movements therefore; for example, it can no longer extend a limb immediately after flexing it, as it does ordinarily in crawling, and locomotion becomes very slow and ungainly.

This characteristic action is most easily seen on exposing an excised frog's muscle to a solution of veratrine; as long as the muscle remains at rest no change is seen, but on stimulating it with a single induction shock, it is found that the height of the contraction is increased and the second part of the curve is extraordinarily prolonged (Fig. 63). Instead of the almost instantaneous return to the base line seen in the normal tracing, the curve shows generally a slight undula-

tion, and then a very slow fall, the period of relaxation generally being 20 to 30 times as long as that in the unpoisoned muscle, and the whole contraction lasting five to ten seconds in favorable circumstances.

Cold and fatigue and high temperature antagonize the veratrine action, and restore the normal tracing; on the other hand, veratrine removes the fatigue effect in the muscle curve. During the prolonged contraction, more heat is formed than in a normal contraction, and the absolute strength of the muscle is also increased, so that it contracts against a greater weight than usual. Larger doses finally paralyze the frog's muscle, the form of the tracing first returning to the normal and the contraction then becoming weaker and disappearing. The irritability of the muscle is not increased by veratrine, but falls in the later stages; the indirect irritability also lessens owing to weakness and final paralysis of the nerve ends. These muscular phenomena are best seen in the frog, but can also be elicited in warm-blooded animals by very large doses; they are not so obvious in the latter because the quantity necessary to induce them is sufficient to affect the respiratory centre. The contraction is not a tetanus, but a prolonged single twitch, as is shown by the electrical reaction. The muscle fibre is affected directly and not through the nerve-endings. Protoveratrine has less tendency to prolong the muscle contraction, but the frog's sartorius exposed to it often shows the typical effect. It paralyzes muscle more readily than veratrine, but has less effect on the nerve terminations.

The **Nerve** fibres are paralyzed by veratrine directly applied to them, and also by protoveratrine though less powerfully.

Circulation.—The ventricular systole of the frog's heart is at first stronger and more prolonged, and soon it dilates only half as often as it did at first, while the auricles maintain their original rhythm. This is evidently due to action on the muscle; the contraction is so prolonged as to limit the number of diastoles, and the ventricle can therefore react only to every alternate contraction of the auricle. After this "half-rhythm" has persisted for some time, the contractions become slower and weaker, and the heart finally comes to a standstill.

In mammals the changes in the circulation resemble those under aconitine except that larger amounts of veratrine are required to produce the same effects and the more obvious symptoms of stimulation of the myocardium are not elicited.

As regards the other alkaloids of this series, jervine, sabadilline, and sabadinine seem to possess the same action as veratrine, but are much less poisonous. Protoveratrine, which has less stimulant effect on the sensory terminations and on the muscle fibres, is more poisonous, its action resembling that of aconitine as much as that of veratrine.

Veratrina (U. S. P.), a mixture of alkaloids obtained from the seeds of Asagræa officinalis, insoluble in water but soluble in alcohol. Dose, 2 mg. ($\frac{1}{30}$ gr.).

Therapeutic Uses.—Veratrine is used in the form of the oleate or ointment as an external application in cases of neuralgia and is certainly a safer remedy than aconite. Veratrum album has been used to reduce the pulse rate and the blood-pressure.

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XXIII. APOMORPHINE.

When morphine is acted on by acids and by some other dehydrating agents, it loses a molecule of water, and a new alkaloid is formed, *Apomorphine* ($C_{17}H_{17}NO_2$).

Through this change the action of the original alkaloid is considerably modified; apomorphine preserves the stimulant, but loses to a great degree the depressant action of morphine on the central nervous system. This stimulant action extends over the whole central nervous system in animals, but is most developed in the "vomiting centre" of the medulla oblongata.

Symptoms.—In man apomorphine in doses of 5–10 mg. ($\frac{1}{12}$–$\frac{1}{6}$ gr.) induces within ten to fifteen minutes nausea and vomiting, accompanied by the usual attendant phenomena, but with no symptoms which cannot be directly included in these. Very often the nausea passes off immediately after the evacuation of the stomach, but when larger quantities have been administered, repeated vomiting and retching may occur. Occasionally depression and sleep follow the emesis after even small doses.

The attendant symptoms are profuse salivation, increased secretion of the mucous glands of the nose, throat and bronchial passages, tears, and a cold perspiration. A feeling of depression and muscular weakness and acceleration of the pulse are also well-known symptoms accompanying nausea and vomiting, and are present after apomorphine. These are all to be regarded as sequelæ of the emetic action, however, and not as due to the direct action of the drug on the glands and other organs. In a few instances the depression and weakness have passed into alarming collapse, but no actual fatality is recorded from the use of apomorphine.

Very small doses of apomorphine may induce the secondary symptoms without actual vomiting. Thus the saliva, perspiration, tears and other secretions may be augmented by quantities which are too small to act as emetics, though there is no question that these are due to the commencing emetic action.

Apomorphine induces vomiting through changes in the medulla oblongata and not by irritation of the stomach. This is shown by the fact that it acts much more quickly and in smaller doses when it is injected hypodermically or intramuscularly than when it is swallowed, and also by the fact that if the medulla is brushed with apomorphine solution, vomiting follows immediately. The movements of vomiting may also be induced in animals after the removal of the stomach and intestine, showing that the condition and the movements of the stomach play an unimportant part in the evacuation of its contents by apomorphine. All the phenomena in man, including the bronchial secretion, the perspiration and other attendant symptoms, are to be ascribed to medullary action.

In dogs and cats, small quantities elicit the same effects as in man, but larger doses are followed by symptoms of general nervous stimulation. In the herbivora, which are incapable of vomiting, these

symptoms follow the injection of comparatively small quantities and are much more marked. The rabbit, for example, becomes restless and easily alarmed; it moves about, climbs up the walls of its cage and gnaws anything it can reach. Circus movements are developed very often, especially in the dog, the animal running unceasingly in a circle and striking against obstacles in its path, apparently unconscious of all its surroundings and overcome by the impulse to continual movement. The respiration is very much accelerated. After very large quantities the movements become less coördinated, and eventually tetanic convulsions set in, during which the respiration ceases, while the heart continues to beat for some time afterwards.

Apomorphine is said to have some anæsthetic effects on the cornea when a solution is dropped upon it. It causes cloudiness and consequent dimness of sight, however, and has not been used practically for this purpose. Apomorphine is not excreted into the stomach like morphine, nor has it been found in the mucous membranes of the air passages, and it is possible that it is all decomposed in the tissues. No tolerance is acquired for it.

The symptoms induced by apomorphine resemble in some degree those following morphine in many animals, for here too the first symptom is vomiting accompanied by signs of excitement, which are, however, generally attended by those of depression of some part of the central nervous system. In man, however, the effects are very different, for apomorphine seems to have lost all the depressant action of the parent body, although here again it must be remembered that morphine occasionally causes vomiting, so that apomorphine does not depart so far from the type of the opium alkaloids as would at first appear.

In the frog, apomorphine causes a transient stimulation of the central nervous system, followed by depression and paralysis.

Apocodeine is formed from codeine in the same way as apomorphine from morphine, but it differs entirely from apomorphine in its action and resembles nicotine in paralyzing the sympathetic ganglia. It causes purgation when injected hypodermically, apparently from removing the normal inhibition of the bowel movements (Dixon). If codeine is heated with hydrochloric acid, apomorphine is formed, and not apocodeine.

Preparations.

Apomorphinæ Hydrochloridum (U. S. P.), expectorant 0.003 G. ($\frac{1}{20}$ gr.), emetic by mouth 0.01 G. ($\frac{1}{6}$ gr.), hypodermic 0.005 G. ($\frac{1}{12}$ gr.); (B. P.), $\frac{1}{20}$–$\frac{1}{10}$ gr. hypodermically, $\frac{1}{10}$–$\frac{1}{4}$ gr. by the mouth.

Injectio Apomorphinæ Hypodermica (B. P.), 1 per cent., 5–10 mins.

Apomorphine hydrochloride is a grayish-white crystalline substance, very soluble in water and turning dark green or even black, especially when kept long in solution. This change in color does not appear to impair its activity appreciably.

Therapeutic Uses.—Apomorphine is used chiefly as an emetic, and for some purposes presents several advantages over the older drugs employed with this object, inasmuch as it acts more promptly and can be administered by the hypodermic needle, while the other emetics cause vomiting by irritating the stomach and have to be given by the mouth, which is a serious drawback in cases of poisoning. The more important of these older drugs are ipecacuanha, tartar emetic (antimony), ammonium carbonate, the sulphates of copper, zinc and alum.

Vomiting is not now such an important method of treatment as it was formerly, and the emetics are less frequently employed to evacuate the stomach than other less heroic measures, such as the passage of the stomach tube. Emesis may be indicated in poisoning, and here apomorphine is especially useful. But in the great majority of cases a better method of treatment is repeated washing of the stomach by means of the stomach tube, for in narcotic poisoning apomorphine not infrequently fails to act, owing to the depression of the vomiting centre, and in corrosive poisoning a certain amount of danger attends its use, as the pressure on the walls of the stomach exerted by the contraction of the diaphragm and abdominal muscles may lead to the rupture of the weakened walls of the organ. In irritant poisoning, on the other hand, the reflex vomiting set up is generally sufficient to empty the stomach, and the indications are rather to allay the gastric irritation than to increase it by causing violent movements of the abdominal walls by apomorphine. Emetics, such as apomorphine, have been used occasionally to cause pressure on other abdominal organs, *e. g.*, on the gall-bladder in order to dislodge a calculus or plug of mucus in the ductus choledochus, but this treatment is not to be advised, owing to the risk of rupture of the gall-bladder. Occasionally emetics are used, especially in children to expel bodies from the air passages, as violent movements of expiration are produced during emesis. Apomorphine is comparatively rarely used for this purpose, however. In cases of choking due to foreign bodies lying in the pharynx, vomiting is often beneficial, but the emetics act too slowly to be of benefit here.

A second use of emetics is in inflammatory conditions of the respiratory passages; the object here is to induce an increased secretion without producing emesis, and very small quantities are therefore used. The special condition in which this class of remedies is of service is bronchial irritation with a sticky mucous secretion which causes cough, but can only be expectorated with difficulty. The indications are for a mild and prolonged action such as can be induced by small doses of ipecacuanha, antimony and similar bodies, rather than for the more transient effect of apomorphine, but the latter has been advised by some authorities.

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XXIV. EMETINE (IPECACUANHA).

Ipecacuanha (Cephaelis or Psychotria Ipecacuanha) has long been used for its emetic and expectorant virtues, and until recently was

believed to contain only one alkaloid, *Emetine*. It has been shown, however, that this so-called principle is really made up of several distinct alkaloids, *Cephaeline* ($C_{28}H_{38}N_2O_4$), *Emetine* ($C_{28}H_{37}CH_3N_2O_4$), and *Psychotrine* and others of less importance; emetine is methyl-cephaeline, and cephaeline is obtained from psychotrine by reduction; they are all three derivatives of isoquinoline, and emetine and cephaeline resemble each other in their action, while psychotrine is said to be almost inert.

Symptoms and Action.—When administered internally emetine has a bitter, acrid taste, and produces a copious salivary secretion, followed later by nausea and vomiting. The drug is generally largely eliminated by vomiting, so that no further effects are observed.

The nausea and vomiting are accompanied by the usual symptoms —muscular weakness and depression, increased secretion of saliva and of mucus by the glands of the throat and respiratory passages, often perspiration and generally temporary acceleration of the pulse.

Quantities which are too small to provoke vomiting, induce prolonged nausea with increased mucous secretion along the respiratory passages and some perspiration.

Emetine possesses a powerful **Irritant Local Action,** which is, however, much more marked in certain individuals than in others. The smallest quantity of the powdered root of ipecacuanha is sufficient to induce in the subjects of this idiosyncrasy considerable swelling and injection of the conjunctival and nasal mucous membranes, with salivation, tears, sneezing, coughing, and bronchial catarrh. When applied to the skin as a liniment, it produces redness, itching and occasionally a pustular eruption, but when injected hypodermically the alkaloids do not irritate the subcutaneous tissues.

The emetic action is mainly due to ipecacuanha irritating the stomach, and is thus a further example of its specific action on the mucous membranes. It is probable that there may be a further action on the medullary centre when large quantities are injected intravenously in animals, but this is not involved in the ordinary methods of administration. If the action were due to the effects of the drug after absorption, vomiting would be caused by a smaller dose injected hypodermically or intravenously than is necessary by the mouth; but it is found that a dose of emetine sufficient to cause vomiting when swallowed, may be injected without any effects whatever. In the case of apomorphine, on the other hand, in which the action is central, the hypodermic emetic dose is smaller than that necessary when it is given by the mouth. The increased bronchial secretion, the perspiration, the acceleration of the pulse and other attendant symptoms are similarly reflex in origin from the gastric irritation and do not indicate any direct action on the bronchi and other organs.

When large doses are injected hypodermically, emetine induces nausea, vomiting, and purging, and blood is frequently voided in the stools, a condition of collapse follows, and the animal generally dies of exhaustion in the course of a few hours after the onset of the symptoms. Very large quantities

injected subcutaneously or intravenously may fail to elicit vomiting, but the collapse symptoms appear, and after some weak convulsive movements, the animal dies of cardiac failure. In those cases in which death follows rapidly on the injection, no pathological lesions may be found after death, but in experiments where smaller quantities are injected, and the animal survivies for eighteen to twenty-four hours, the stomach and intestine often exhibit the appearances of acute gastro-enteritis. The mucous membrane is swollen, congested, and often covered with a muco-purulent secretion or studded with ecchymoses, and in dogs ulceration is often present. A lesion which is not by any means constant, but which occurs in a considerable number of animals and especially in rabbits, is œdema of the lungs.

The gastric and intestinal symptoms which follow from these large hypodermic doses suggest that emetine is excreted by the mucous membranes of the alimentary canal, and that it induces irritation and inflammation in the course of its excretion. In man, vomiting has followed the hypodermic injection of four grains of emetine, but one grain administered in this way has no such effect.

Emetine injected into a vein weakens the heart's action, and induces a fall of blood-pressure, but when it is injected subcutaneously or given by the mouth, the heart is not affected directly.

In the frog emetine does not cause vomiting, but a slowly advancing central paralysis follows its injection, the spontaneous movements ceasing early, and later the reflex excitability disappearing. The contractions of the heart are rendered weak and irregular, and eventually cease from paralysis of the cardiac muscle.

Ipecacuanha has long enjoyed a reputation in one form of tropical dysentery, and the discovery that the cause of this form of dysentery was an amœba (Entamœba histolytica) was soon followed by Roger's statement that emetine has a specifically poisonous action on this parasite. This specific toxicity cannot be demonstrated in ordinary forms of amœba, nor in other protozoa, and even the entamœba of dysentery is not strikingly susceptible to emetine when exposed to it in the test-tube; sometimes 1 per mille or even 1 per cent. of emetine has not killed the amœba in the test-tube within an hour. On the other hand the effects in cases of dysentery treated with emetine are very saitsfactory and the entamœba disappears from the stools and tissues. The quantity of emetine that comes in contact with the parasite must be even smaller than that of quinine in cases of malaria, and the equivalent concentration is harmless to entamœba outside the body. There is thus some difficulty in assigning the success of the treatment to a directly poisonous action on the parasite. And a further complication is met in the fact that kittens infected with entamœba histolytica from dysentery in man, are not improved by treatment with emetine. It has therefore been suggested (Dale and Dobell) that emetine acts in human dysentery not as a direct poison to the entamœba but by some change induced in the tissues of the host, which renders these a less suitable harborage for the parasite.

Emetine and cephaeline, the two chief alkaloids of ipecacuanha, resemble each other closely in their effects, cephaeline being somewhat more irritant than emetine. Ipecacuanha owes its action to the alkaloids, and differs from them only in acting more slowly and in having less

tendency to cause purging owing to its containing a large amount of tannin. The relative action of the two alkaloids in dysentery has not been accurately determined, but emetine is superior to cephaeline.

Preparations.

U. S. P.—**Ipecacuanha**, the root of Cephaelis Ipecacuanha or of C. acuminata, contains at least 1.75 per cent. of alkaloids. The powdered root is prescribed in dysentery in quantities of 2–4 G. (30–60 grs.); emetic, 1 G. (15 grs.); expectorant, 0.065 G. (1 gr.).

Fluidextractum Ipecacuanhæ, (2 per cent. of alkaloids) expectorant, 0.05 mil (1 min.); emetic, 1 c.c. (15 mins.).

Syrupus Ipecacuanhæ, (about 0.12 per cent. of alkaloids) expectorant, 1 mil (15 mins.); emetic, 15 mils (4 fl. drs.).

Pulvis Ipecacuanhæ et Opii (10 per cent. each of ipecacuanha and opium), Dover's Powder, 0.5 G. (8 grs.).

Emetinæ Hydrochloridum, a white crystalline powder freely soluble in water, 0.02 G. ($\frac{1}{3}$ gr.) hypodermically.

B. P.—**Ipecacuanhæ Radix**, the dried root of Psychotria Ipecacuanha, (2 per cent. of alkaloids) expectorant, $\frac{1}{2}$–2 grs.; emetic, 15–30 grs.; in dysentery, 30–60 grs.

Vinum Ipecacuanhæ, expectorant, 10–30 mins; emetic, 4–6 fl. drs.

Pulvis Ipecacuanhæ Compositus, Dover's Powder, 10 per cent. each of ipecacuanha and opium, 5–15 grs.

Emetine Hydrochloride, (not official.) Dose, hypodermically $\frac{1}{4}$–1 gr.

Therapeutic Uses.—Ipecacuanha has been largely employed as an emetic, and although it has been replaced for some purposes, notably in cases of poisoning, by apomorphine, it still has a certain field of usefulness in cases in which an emetic is indicated, but in which the hypodermic method is objectionable, as in children. At present ipecacuanha is used chiefly as an expectorant in the treatment of inflammatory conditions of the respiratory passages. For this purpose it is prescribed in smaller quantities than those necessary to produce emesis. It acts indirectly through its nauseating properties, and has the advantage that its action is much more prolonged than that of apomorphine, and at the same time is not so unpleasant as that of several metallic substances, such as tartar emetic, which are used for the same purpose. It increases the secretion of the bronchial mucous membrane, and further tends to render it more fluid, so that the mucus can be coughed up more easily. The increased secretion may also be of service by protecting the inflamed and irritable membrane from the cold air and thereby lessening the cough; opium is often added in order to further allay coughing by depressing the centre, the well-known Dover's powder being a favorite prescription for this purpose. When the secretion of the bronchi is already excessive, and the cough is rather to be encouraged than repressed, these preparations are of course contra-indicated.

Ipecacuanha is also employed as a diaphoretic, either alone or more commonly as Dover's powder. The perspiration is not so copious as that following pilocarpine and other sudorifics, but resembles rather that produced by warmth applied to the skin. Dover's powder is

therefore a common remedy in chills and in commencing catarrh of the respiratory passages.

Ipecacuanha root was formerly used in amœbic dysentery. But very large quantities were required, and it was difficult to avoid nausea and vomiting; opium and morphine were added with this object, and it was proposed to enclose the powder in keratin or salol, which prevent it acting on the stomach, but are dissolved in the duodenum and thus free the ipecacuanha in the intestine. But all these cumbrous methods have been rendered obsolete by the introduction of emetine into therapeutics. Rogers showed that the hypodermic injection of the alkaloid is more efficient than the ipecacuanha treatment in amœbic dysentery and in its sequelæ, hepatitis and hepatic abscess. After the hypodermic injection of 1–2 grs. in divided doses of $\frac{1}{2}$–$\frac{3}{4}$ grs. each, the amœbæ disappear from the stools and from the liver in a considerable proportion of cases, and an immediate improvement in the symptoms follows. The treatment may be continued (1 gr. each day) until 10–12 grs. in all have been given. It should then be discontinued, as the prolonged use of emetine is liable to set up irritation of the bowel. The injection is unattended by pain, irritation or any other symptom; the soluble hydrochloride is dissolved in the ordinary way. Still better results are obtained by the use of the double salt emetine-bismuth iodide, given by the mouth; this is entirely insoluble and does not act in the stomach, while it is decomposed in the intestine so that the emetine can unfold its action. A dose of 3–4 grs. should be given daily until about 40 grs. in all have been taken; this is curative in the majority of cases. In amœbic liver abscess, Rogers removes the pus by aspiration and then injects into the cavity a grain of emetine dissolved in 1–2 oz. of sterile saline solution to destroy the amœbæ. The action of emetine in these amœbic diseases can only be compared with that of quinine in malaria; and, as in the case of quinine, the free protozoa disappear while encysted forms escape, and may give rise to relapses. Emetine is valueless in dysentery from bacillary infection and most other intestinal disorders but has been recommended in sprue.[1]

Ipecacuanha has been recommended in very small quantities as a stomachic, even in cases of vomiting, and its action on the mucous membrane might be expected to be of value in some cases; but it very often fails to have any effect, and is not widely used for this purpose.

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[1] Many other drugs have been recommended in amœbic dysentery, but though some destroy the amœba in test-tube experiment, they have not proved valuable in treatment. An extract of Castela nicholsoni, or Mexican bitter bush (Chaparro amargosa) has sometimes proved effective in cases in which emetine was unsuccessful.

XXV. COLCHICINE.

Colchicine and *colchiceine* are two nearly related bodies found in the seeds and corm of Colchicum autumnale, which owes its activity to their presence. Colchicine, $(CH_3O)_3C_{10}H_3(C_6H_6O).OCH_3.NHCOCH_3$, is the methyl ester of colchiceine, which is much less active pharmacologically. Colchicine is feebly basic, while colchiceine is slightly acid in reaction.

Symptoms.—No symptoms whatever follow the use of colchicum in small quantities. Large doses, corresponding to 4–5 mgs. of colchicine, cause diarrhœa with some griping in susceptible persons, and in the therapeutic use of the drug purging is often observed; symptoms only arise several hours after the drug is administered, and this interval is not shortened by increasing the dose.

In poisoning with colchicine, whether given by the mouth or injected hypodermically, the symptoms arise from the alimentary tract. Pain in the gastric region is followed by salivation, nausea, vomiting, and diarrhœa. At first the evacuations are the ordinary contents of the stomach and intestine, but afterwards a quantity of sticky mucous fluid may be ejected, often streaked with blood. Later, a condition of depression, apathy and collapse follows, and the movements become slow and difficult, more especially in the posterior extremities, which eventually become completely motionless; the paralysis then progresses upward until the movements of the fore limbs and respiratory muscles are involved, when death occurs from asphyxia. In man the intelligence remains until death, though there is generally some giddiness and precordial anxiety and occasionally some confusion or even delirium preceding the collapse.

In mammals poisoned with colchicine the alimentary canal exhibits all the appearances of acute gastro-enteritis, with numerous ecchymoses, especially in the upper part of the bowel. In less acute cases these inflammatory symptoms are less marked, and in man there is seldom more than catarrh of the duodenum.

The **Circulation** is but little affected apparently. In animals, the blood-pressure and heart rhythm remain normal, and though a small, rapid pulse may be one of the features of the poisoning in man, this is due to the collapse rather than to any direct action on the circulatory organs.

The **Respiration** is slow, but is deep and full at first. Later it becomes shallow, and the failure of the centre is the cause of death, the heart continuing to beat for some time afterwards.

The **Movements of the Bowel** are much hastened when the symptoms set in, and Dixon states that colchicine acts on the bowel in the same way as pilocarpine, and that its action is antagonized by atropine; but this is entirely inadequate to explain the acute inflammatory appearances, which are evidently due to an irritant action on the mucous membrane. Increased movement is said to be induced in

the plain muscle of the spleen, uterus, and bronchial muscle from a pilocarpine-like action.

When **Locally Applied** to sensitive mucous membranes, or when injected hypodermically, colchicine is intensely irritating, producing redness and prickling in the skin, and a burning sensation in the mouth and throat.

The **Nervous Symptoms** are supposed by some to be due to a direct action on the central nervous system, but are to be ascribed rather to a condition of collapse produced indirectly through the action on the abdominal organs.

The influence of colchicine on the **Kidneys** varies, for in some cases complete anuria is produced for many hours, while in others the urine is slightly increased. The constituents of the urine are not materially altered by ordinary therapeutic doses of colchicum, and, in particular, the uric acid shows no constant change in amount. In animals bloody urine is sometimes passed after colchicine.

In poisoning with colchicine the leucocytes are at first reduced in the peripheral circulation, but afterwards increase to beyond the normal number.

All of these symptoms are exactly those caused by a large number of poisons, including some of the bacterial toxins and the heavy metals. Many local irritants when injected into the blood or when absorbed from the subcutaneous tissue or the alimentary canal, exercise an immediate, local action, which betrays itself in pain or ecchymosis and swelling at the point of injection, but these symptoms pass off in a short time and the animal becomes apparently normal for many hours or even days. At the end of this time, however, symptoms begin to develop at two points—in the alimentary canal and in the kidneys. The reason probably is that the poisons are excreted at these points and are either freed from some harmless combination in which they have circulated in the tissues, or perhaps collect in larger quantities in the excretory organs; it is believed that the seat of action is in the walls of the capillaries, which are dilated, rather than in the tissues in which they are embedded, and these poisons are therefore often termed "capillary poisons." At any rate, irritation and later acute inflammation are set up at these points. At first the irritation excites only diarrhœa and diuresis, but as it goes on, gastro-enteritis and anuria or hæmaturia may be produced. The symptoms from the intestine and kidney may not be equally well marked; at one time the one becomes inflamed while the other is only subjected to mild stimulation, while at other times both are the seat of acute inflammation. The inflammation of the bowel produces a condition of collapse, which is seen also in various intestinal diseases, such as cholera. Sometimes the poisons (and also cholera) produce no very marked symptoms of gastro-intestinal disorder, but rather those of collapse; here it may be supposed that there is general paralysis of the capillaries, similar to that in secondary shock from injury.

A number of colchicine derivatives have been examined by Fühner, who finds that colchiceine has little action and that oxycolchicine is equally inactive in mammals, but is very poisonous in frogs, in which it prolongs the muscle curve in the same way as veratrine and also causes strychnine-like convulsions. Colchicine itself only acts in the frog after a latent period extending over some weeks, as a general rule.

Preparations.

Colchici Cormus (U. S. P., B. P.), the corm or bulb of Colchicum autumnale, containing 0.35 per cent. of colchicine, 0.25 G. (4 grs.).

Extractum Colchici Cormi (U. S. P., B. P.), 0.06 G. (1 gr.); B. P., $\frac{1}{4}$–1 gr.

Vinum Colchici (B. P.) (10–30 mins.).

Colchici Semen (U. S. P.), **Colchici Semina** (B. P.), the seed of Colchicum autumnale, containing 0.45 per cent. of colchicine, 0.2 G. (3 grs.).

Tinctura Colchici Seminis (U. S. P.) (0.04 per cent. colchicine), 2 mils (30 mins.).

Tinctura Colchici (B. P.), 5–15 mins.

Colchicina (U. S. P.) ($C_{22}H_{25}NO_6$), an alkaloid obtained from colchicum, pale yellow in color, with a bitter taste and characteristic odor; soluble in 22 parts of water and in alcohol. Dose, 0.5 mg. ($\frac{1}{120}$ gr.).

Therapeutic Uses.—Colchicum has long been used in gout on purely empirical grounds. In fact, the pathology of gout is so obscure that no rational treatment for it can be looked for at the present day, and the efficacy of colchicum in this disease can, therefore, be argued solely from clinical experience. There is no doubt that the pain and inflammation around the joint in an acute attack of gout are relieved by colchicum, often without any other obvious effect, but sometimes only after enough has been given to cause some diarrhœa. In the intervals between the acute attacks, colchicum does not appear to have any beneficial effect, and it is not clear that continued treatment wards off the attacks. The uric acid excretion is not altered by colchicum treatment in gout, nor in health. And though some investigators have stated that the excretion of endogenous uric acid is increased by colchicum, while that derived from the food remains unaffected, this has not been established. The failure to explain the action of colchicum in gout, by changes in the uric acid elimination or in any other way, does not diminish the importance of the clinical evidence that it is beneficial in this disease, but merely indicates that further research is necessary before the problem can be solved.

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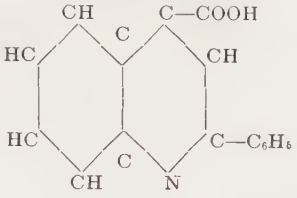
XXVI. PHENYLQUINOLINE CARBONIC ACID (ATOPHAN).

A number of compounds of the type of quinoline carbonic acid have been shown by Nicolaier to increase the amount of uric acid excreted in the urine in a remarkable way; among these the phenyl-quinoline

carbonic acid is the most efficient and has been introduced into medicine under the name of atophan or cinchophen.



A nearly related substance, the ethyl ester of a methyl-atophan is issued under the name of *Novatophan.*

Atophan may be taken in large quantities (100 grs.) without any obvious symptoms, but considerably smaller doses (30 grs.) may suffice to increase the uric acid of the urine threefold; in other cases the augmentation is not so great, but it is almost always 40 or 50 per cent. The urine is but little changed in amount but is often turbid when passed, and deposits quantities of urates on standing; this turbidity may appear within forty-five minutes of the administration of atophan. No other constituent of the urine is altered appreciably in amount as a general rule. This increased elimination of urates and uric acid occurs in persons on ordinary diet and also on a purine-free diet, in which the uric acid excreted can arise only from the tissue change. When atophan is given for one day only, the excretion of uric acid rises immediately, and the following day it sinks below the normal amount, as if the first large excretion had exhausted the supply. When it is given continuously for some time, the excretion falls rapidly after the first day and may reach the normal or even below it on subsequent days; very often however, more uric acid is excreted each day than normally, although the marked excretion attained at first is not repeated.

The more rapid excretion of uric acid is attended by a fall in the uric acid content of the blood (Folin and Lyman). The action is thus a direct one on the kidney, which is more readily permeated by the urates, so that those previously retained in the blood through the difficulty attending their elimination by the kidney, now escape in the urine. The kidney is generally changed only in relation to the uric acid, but in some cases of retention of urea and chlorides, these are said to be excreted in larger quantities also. The rapid removal of the urates of the blood and tissues appears often to increase the formation of uric acid in the body, for the continued treatment with atophan is attended by an abnormally large amount of uric acid in the urine even when it extends to weeks in duration. And it has been found that under atophan more uric acid is eliminated in the urine from a given quantity of nucleinic acid than can be obtained in ordinary circumstances. The formation of uric acid in the organs is thus favored by the atophan treatment, but this appears not to be due to any direct action, but to be the result of the rapid excretion, which leads to a fall in the urates of the blood and thus makes room for fresh urates from the organs; possibly the reduced

amount of urate in the blood may change the direction of decomposition of nucleinic acid, some which would normally be excreted as urea, now following the alternative path to end as uric acid. All the evidence points to atophan increasing elimination by the kidney rather than to any direct influence on uric formation; probably the normal reabsorption of urates in the tubules is hindered by atophan. Abl finds that calcium and atropine lessen the excretion of uric acid under atophan. Atophan appears to undergo decomposition in the tissues for the most part, though some appears in the urine unchanged. Like so many other aromatic substances, atophan reduces fever temperature and lessens pain (see Antipyretic group).

Acidum Phenylcinchoninicum (U. S. P.), *Atophan* ($C_{16}H_{11}NO_2$), forms small colorless crystals with a bitter taste, almost insoluble in water but soluble in alkalies and acids. Dose, 2–4 G. (30–60 grs.) per day in divided doses, given as powder or tablets.

Atophan has been used in gout chiefly, in which it increases the uric acid elimination in the same way as in health and does not induce any other symptom. This free removal of uric acid appears to be of benefit in the disease and several observers state that the deposits of urates (tophi) are lessened in size and the chronic inflammation of the joints is relieved; others have observed less benefit and deny that uric acid deposits are reabsorbed under atophan. There seems no doubt that atophan fails to relieve the pain and inflammation of an acute attack in the way which has given colchicum its reputation in this disease.

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XXVII. SAPONIN, SAPOTOXIN AND SOLANINE.

This group comprises a series of glucosides which are very widely distributed in plants and which resemble each other in certain reactions with living cells. They contain no nitrogen and are typical glucosides, but their chemical structure is otherwise unknown; some have an acid reaction. The most poisonous among them are designated by the general term of *Sapotoxins,* while *Saponin* may be used to include the less active and the wholly innocuous members of the group.

These glucosides reduce the surface tension of water to a very marked degree, and even dilute solutions form froths like soap when shaken up. From this property the plants derive their popular names of soap-root or soap-bark. The reduction of the surface tension also explains their property of holding insoluble bodies in suspension. The saponins have

a peculiar affinity for lecithin which they dissolve, while cholesterin forms an insoluble chemical compound with many of them; they tend to be deposited on the surface of cells with which they come in contact.

Saponins or sapotoxins are found in about 150 species of plants. The chief of these are: *Quillaja saponaria*, or soapbark; *Saponaria officinalis*, or soapwort; *Cyclamen Europeum*, or sowbread; *Polygala senega; Agrostemma githago*, or corncockle; *Gypsophila struthium* and other species; *Chamælirium luteum*, or blazing star; *Smilax*, various species, including those known as sarsaparilla.

In addition to the plants which owe their action to the presence of these bodies, a number of drugs contain saponins along with other more important principles. Thus an almost inactive saponin (*digitonin*) is met with in digitalis, and similar saponins occur in several others of the digitalis series; helleborein appears to stand midway between the true digitalis glucosides and the saponins in its action.

The most poisonous sapotoxins are those of quillaja, agrostemma, gypsophila, and cyclamen, and some saponins may be regarded as harmless when taken in ordinary quantity.

Another body closely resembling the saponins in action is *Solanine*, a glucosidal alkaloid found in many species of Solanum, such as S. nigrum (black nightshade), S. dulcamara (bittersweet), S. tuberosum (potato), and probably in some species of Scopola. Solanine breaks up on being heated with acids into sugar and a base, *Solanidine*, which retains the poisonous action. Some interest attaches to solanine from its having been held responsible for some instances of widespread poisoning from the use of potatoes. But it is now known that the symptoms arose from putrefactive bacteria and their products, and that solanine is never present in the tuber of the potato in sufficient quantity to be noxious.

Action.—The sapotoxins have a harsh, acrid, taste, and when swallowed provoke nausea and often vomiting, with pain and colic, and less frequently diarrhœa. They are not absorbed by the normal epithelium of the alimentary canal, and seem to undergo decomposition in the bowel, and therefore fail to produce general symptoms. Thus pigs feed with avidity on Cyclamen and are unharmed by it unless some lesion of the intestine is present. The unbroken skin is not affected by a single application as a general rule, but when they are applied repeatedly or rubbed in as ointment they cause irritation and pustules. Absorption is extremely slow from the subcutaneous tissues, in which they act as irritants, however, and produce inflammation and suppuration. The sapotoxin derived from Agrostemma differs from the others in being absorbed fairly rapidly from the alimentary canal and from the subcutaneous tissues, so that more dangerous symptoms may arise from it than from the other members of the series.

When these bodies are injected directly into the bloodvessels, they induce much more characteristic changes, which very often prove fatal after a longer or shorter interval. Very large quantities thus injected may kill animals within a few minutes from respiratory

paralysis, and no characteristic appearances are to be found post-mortem. Smaller doses induce depression, loss of appetite, sometimes vomiting and diarrhœa, general weakness and collapse, with some dyspnœa and irregular, feeble pulse. Weak convulsions appear just before the failure of the respiration, while the heart continues to contract for some minutes longer. In these cases ecchymoses are found in the serous membranes, pericardium, pleura and peritoneum, and occasionally in the kidneys. Endocarditis has been observed in some instances, but the most important alterations occur in the stomach and intestines, the mucous membrane of which is swollen and congested and contains numerous blood extravasations. The lymphatic glands of the abdominal cavity are also swollen and congested and often filled with hæmorrhages. Occasionally the kidneys are found to contain numerous blood casts, filling the lumen of the tubules, and in these cases albumin and hæmoglobin appear in the urine before death; these are more often elicited by solanine than by the sapotoxins. In Cyclamen poisoning (from intravenous injection) hæmoglobinuria is one of the earliest symptoms.

The property of dissolving lecithin which is characteristic of this series renders them poisonous to living tissues when they come in contact with them in sufficient concentration. On the other hand, cholesterin deprives them of toxicity by forming inactive cholesterides, but as a general rule the cholesterin is not in sufficient amount to neutralize them completely. Their irritant action on the mouth, throat and stomach is the cause of the nausea and vomiting observed when they are administered in this way, and they cause sneezing and coughing from the same action in the nose and throat. On other mucous membranes, such as the conjunctiva, and in wounds, they cause similar irritation and inflammation, which may be followed by suppuration. A form of local anæsthesia often follows this irritation, the termination of the sensory nerves apparently being benumbed, but the preliminary irritation precludes their use for this purpose.

When the individual organs are exposed to the action of saponin bodies by the direct application of solutions to them, a similar poisonous action is elicited. Muscle contracts more weakly even in dilute solutions, is eventually entirely paralyzed, and is altered in structure, the transverse striæ of voluntary muscle and of the heart becoming very indistinct. Nerves exposed to solutions are also paralyzed in the same way, and the movements of cilia cease at once when they are exposed to sapotoxin bodies. The blood undergoes characteristic changes when it is acted on by saponin either in the vessels or in the test-tube. The red blood cells undergo rapid destruction and the hæmoglobin is freed in the plasma. Even one part of cyclamin added to 100,000 parts of diluted blood completely lakes the red-blood cells, while hæmoglobin appears in the serum when considerably less poison is added. The other saponin bodies act less powerfully in this direction than cyclamin, but still produce distinct solution of the substance of the red corpuscles. When a saponin is injected into the blood of

a living animal this destruction of the red-blood cells takes place to some extent, and the plasma contains hæmoglobin, while the blood corpuscles are considerably diminished in number. This hæmolytic action is not the result of changes in the hæmoglobin, but is due to the dissolution of the stroma of the corpuscles, through the solvent action of the saponin on the lecithin. This solvent action occurs more readily when the blood cells are suspended in normal salt solution than in the plasma or serum, because the cholesterin of the serum forms inactive compounds with the saponins. Even when the hæmoglobin in the corpuscles is coagulated and saponin fails to induce laking, the structure of the corpuscle is altered, as is shown by its reaction to salts (Stewart).

The frog's heart perfused with sapotoxins is arrested in systole in the same way as by digitalis, and the mammalian heart is also weakened when saponin is injected intravenously, though it continues to beat after the breathing has ceased. The central nervous system is also susceptible to the changes in the lecithin in the nerve cells, and the failure of the respiratory centre is the cause of death. In many experiments the collapse from the irritation of the alimentary canal proves fatal, but in others in which large doses are immediately fatal the poison is believed to act directly on the nerve cells, whose activity is suspended by changes in the distribution of the lipoids similar to that under the alcohol-chloroform group. A similar central nervous action may explain experiments in which only small quantities of the poison have been injected, but in which the animal dies after a few days, presenting no distinct symptoms except general weakness and depression.

The sapotoxins are poisonous to invertebrates, unless they are protected by a shell through which the poisons cannot penetrate. Thus the amœba and other simple organisms cease their movements, while intestinal worms are first excited and then paralyzed in the presence of some of the group.

Therapeutic Uses.—The drugs of this group are all quite superfluous. They may be used to increase the bronchial secretion in cough through the nausea caused by their slight irritant action in the stomach, but they have no advantages over such drugs as ipecacuanha; syrup of senega is often prescribed in expectorant mixtures for this purpose. Sarsaparilla has been supposed to have an obscure action on the nutrition, and has some reputation in the treatment of syphilis, but there is no reason to believe that it is of any service here or in any other condition, although it may be used as a vehicle for the administration of mercury and iodide of potassium. Quillaja has been used to some extent as an expectorant, more largely to form emulsions and to suspend insoluble powders. Its irritant action ought, however, to preclude its use for this purpose. It is frequently stated that members of the sapotoxin series are antidotes in digitalis poisoning, but this is incorrect.

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XXVIII. PRUSSIC ACID.

Prussic, or hydrocyanic, acid differs entirely from the other acids in its pharmacological action, and has therefore to be described apart from them.

The pure acid is scarcely ever seen save in the chemical laboratory, and is a dangerous body to handle, as it is very volatile and when inhaled may produce death within a few seconds. It is generally met with in a very dilute solution, which is formed by the decomposition of one of its salts.

In nature, prussic acid occurs in the secretion of some of the myriapoda, and in the decomposition products of a few glucosides, of which *Amygdalin* is the best known. Amygdalin is in itself practically inactive, but may be decomposed by dilute acids or by a ferment, emulsin, which is generally found associated with it in plants (see p. 66). Prussic acid may be formed from the amygdalin of the bitter almond and the kernels of such fruits as the apple, cherry, plum, etc. and from the bark and leaves of several trees including the laurel (Prunus laurocerasus). A paste formed from bitter almonds has given rise to symptoms from the prussic acid, but a more dangerous substance is the oil of bitter almonds, which consists of benzaldehyde and prussic acid in a loose combination and in very varying proportions. Sweet almonds contain no amygdalin and are therefore harmless. Laurel water and the preparations of Virginian cherry bark contain benzaldehyde and prussic acid in too small quantity to have any poisonous action. Several plants which contain glucosides similar to amygdalin have given rise to poisoning in cattle, probably from prussic acid being freed from the glucosides in the intestine.

Prussic acid and its salts have practically the same action, although none of the latter are so poisonous as the free acid. Cyanogen, $(CN)_2$, also resembles prussic acid in its effects, but is not so active.

The ferrocyanides and other double cyanides are in most cases harmless but other compounds, from which prussic acid is formed in the organism, are poisonous. The organic combinations containing the—CN radical form two series, the *Nitriles*, in which the nitrogen is trivalent (*e. g.*, $CH_3—C{\equiv}N$), and the *Isonitriles*, or *Carbylamines*, in which the alkyl is attached to the nitrogen (*e. g.*, $CH_3—N{\equiv}C$). These compounds are all much less poisonous than prussic acid, and the nitriles are said to differ from it in their effects, inasmuch as the chief symptoms caused by them arise from gastro-intestinal irritation. The isonitriles are more poisonous than the nitriles and resemble the acid more closely in their action. Both nitriles and isonitriles give rise to the formation of prussic acid in the tissues.

Symptoms and Action.—Prussic acid acts upon almost all forms of living matter; in mammals the central nervous system is especially susceptible. The fatal dose in man is believe to be about 0.05–0.08 G.

(1 -1½ gr.) of the pure acid, so that it is less poisonous than some of the alkaloids and glucosides. It acts so rapidly, however, that it must be regarded as a most dangerous poison. One volume of prussic acid in 2000 of air is generally fatal to animals.

After very large doses in mammals, there may be practically no symptoms; the animal falls to the ground with a slight convulsive movement or a scream, and death follows in a few seconds from simultaneous arrest of the heart and respiration.

In smaller quantities prussic acid has a bitter, acrid, burning taste, which induces salivation, and is followed by numbness in the mouth and throat. A sensation of warmth in the stomach is followed by nausea and vomiting, confusion and headache, dyspnœa, slow pulse and general muscular weakness. The pupils are widely dilated and the eyeballs protrude, as generally occurs in asphyxia. Unconsciousness follows, and then violent convulsions, which pass into paralysis with involuntary evacuation of the contents of the bladder and bowels; the respiration becomes extremely slow and eventually ceases, while the heart continues to beat for some time afterwards.

The **Central Nervous System** is first stimulated and then paralyzed; the convulsions resemble those produced by stimulation of the hind-brain, although the subsequent paralysis seems to include all parts of the central axis.

Striated and unstriated **Muscles** and the **Nerves** are weakened and eventually paralyzed when suspended in an atmosphere of the gas, but they are not affected in poisoning; the nerves are more readily poisoned than the muscles. When prussic acid in solution is applied locally to the **Skin** it produces numbness and partial loss of sensation, but this does not follow in general poisoning.

The **Respiration** is rendered quicker and deeper by the injection or inhalation of small quantities of prussic acid. After larger quantities, the acceleration is often interrupted by a prolonged pause after which the breathing returns spontaneously. In fatal poisoning no such return occurs, and after very large doses the breathing may cease within a few seconds.

The **Circulation** is altered mainly through the action on the central nervous system, although prussic acid also acts directly on the heart. The stimulation of the inhibitory centre generally slows the pulse, but this is accompanied by a very considerable rise in blood-pressure from increased activity of the vaso-constrictor centres. Later, the blood-pressure falls, from the depression of the vasomotor centre; the heart is now directly affected, the chambers being greatly dilated, and block often appearing.

Nutrition.—Prussic acid exercises a depressant action on protoplasm in general. Both plants and animals are retarded in their movements and in their nutritive processes by its presence, although they may recover and show no subsequent deterioration, provided the poison acts only during a short time and in sufficient dilution. For example, the development of seeds is hindered by the presence of prussic acid, but

proceeds when it is withdrawn; yeast cells cease their activity, and the insectivorous plant Drosera no longer moves its tentacles in the presence of cyanides or prussic acid (Darwin). This action in plants arises from the poison arresting the respiration of the cells through paralysis of the oxidizing ferments, for no carbonic acid is given off nor oxygen absorbed. The hydrolytic ferments are less affected or may be unchanged in activity.

The effects of prussic acid on the mammalian tissues were first examined by Geppert in a long and careful research. He found that the oxygen absorbed by the tissues was much lessened by it; even during the most powerful convulsions after prussic acid, the absorption of oxygen is often distinctly lower than in the normal resting animal and the carbonic acid formed by the tissues falls correspondingly. The

FIG. 64

Tracing of the movements of the diaphragm (respiration) of the rabbit under a large but not fatal dose of cyanide of potassium injected intravenously. *A–B*, normal respiration. At *B* 1 mg. injected; the respiratory movements are much larger. At *C* recovery. Note the short duration of the stimulation.

imperfect oxidation is due to the tissues being unable to absorb the oxygen brought to them by the blood cells; in fact, a change occurs in the protoplasm which retards the normal respiration of the cell. In consequence of this, the oxyhæmoglobin of the blood is not reduced in the capillaries, so that the venous blood has the same bright-red color as the arterial. Prussic acid is rapidly changed to harmless products in the tissues, however, provided a lethal dose has not been given, and as this process goes on, the protoplasm recovers its oxygen-absorbing power, the expired air becomes less rich in oxygen and richer in carbonic acid, and the venous blood assumes its ordinary dark color. The usual results of imperfect oxidation in the tissues are seen in an increase in the sugar and lactic acid in the blood, and augmented nitrogen, urea and unoxidized sulphur in the urine.

This lessened O_2 absorption in the tissues, arises from the intracellular ferments being paralyzed in animals in the same way as in plants. In fact the whole action of prussic acid is so like that of asphyxia, that there is every reason to hold that it is limited to this arrest of oxidation.

Prussic acid is changed to sulphocyanides in the tissues, and is partly excreted in the urine in this form, while part of it undergoes further and unknown changes. This combination of prussic acid and sulphur bodies seems to arise by simple chemical processes, without the intervention of living protoplasm being necessary.

There is no combination of hæmoglobin formed with cyanide in the living tissues, the change in the color being due to the oxyhæmoglobin not being reduced in them. If normal blood is brought in contact with a solution of peroxide of hydrogen, it effervesces, owing to the liberation of oxygen by the peroxidase ferment, and the peroxide being all decomposed in this way, the oxyhæmoglobin remains unchanged; if, however, prussic acid be present, no effervescence occurs, because the peroxidase is rendered inert, and the hæmoglobin is at once changed to methæmoglobin from the oxidizing action of the peroxide, which is no longer dissipated.

Preparations

Acidum Hydrocyanicum Dilutum (U. S. P., B. P.), a 2 per cent. solution formed from potassium ferrocyanide or silver cyanide. It is a colorless fluid with a characteristic smell and taste, and ought not to be kept long, as it is liable to decomposition; much of that actually used in medicine is partially decomposed and therefore under 2 per cent in strength. Dose, 0.1 mil ($1\frac{1}{2}$ mins.); B. P., 2–5 mins.

A number of other preparations contain prussic acid in small quantities along with benzaldehyde, and are used as flavors (page 66).

Therapeutic Uses.—Prussic acid might be eliminated from therapeutics without loss. It was formerly applied to soothe itching surfaces, and in the vomiting of pregnancy, but is hardly used for these purposes now. It was also a constituent of expectorant mixtures in which it was supposed to relieve cough. Recently it has been injected intravenously in the form of sodium cyanide as a respiratory stimulant; but this heroic treatment is not likely to appeal to many.

In **Poisoning** with prussic acid or the cyanides, the treatment is thorough evacuation of the stomach, warmth, and general measures against collapse. Artificial respiration should be resorted to when necessary, as a cyanide is comparatively quickly rendered inactive, and the recovery is rapid when it once sets in. The intravenous injection of sodium sulphide or hyposulphite has been advised to form the harmless sulphocyanide, and animals seem to be able to survive an otherwise lethal dose when this is done. This, however, like other proposed antidotes, is not generally applicable in an emergency, and if prussic acid is not fatal within a few minutes, recovery may be looked for without any treatment. But in many cases life is extinct before medical aid can be called.

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XXIX. ASPIDOSPERMA, OR QUEBRACHO.

The bark of Quebracho blanco (Aspidosperma quebracho) contains a number of alkaloids which are probably very similar in chemical composition and which seem to possess almost the same action. They are *Aspidospermine*, *Aspidospermatine*, *Aspidosamine*, *Hypoquebrachine*, *Quebrachine*, and *Quebrachamine*. Another species of Aspidosperma, Payta, contains two alkaloids, *Paytine* and *Paytanine*, of which Paytine resembles closely the Quebracho alkaloids in its pharmacological action. Quebrachine is also found in the bark of the Yohimbehe tree (Corynanthe yohimbi) and was formerly known as *yohimbine*.

These alkaloids all produce nausea, but even after large doses vomiting does not occur except after Aspidosamine. The nausea is accompanied by the usual concomitant symptoms—salivation, increased secretion of mucus in the respiratory tract, depression and alternately rapid and slow pulse. Large quantities often cause symptoms of central nervous stimulation, tonic contractions and convulsions. The respiration is quicker and deeper after small quantities, but after lethal doses becomes slow and weak, and finally ceases. Periodic respiration often occurs before the final standstill, a series of deep dyspnœic movements alternating with several shallow, insufficient ones. The failure of the respiration is the cause of death in mammals, the heart continuing to contract for some time longer. Quebrachine is the most powerful of these alkaloids, aspidospermine nearly rivalling it, while quebrachamine and aspidosamine are less active.

These symptoms are generally ascribed to a direct action on the central nervous system, which is first stimulated and then depressed. The chief seat of action seems to be the medullary centres and the spinal cord, although the basal ganglia may also be more or less involved. The stimulation of the medullary centres explains the nausea and vomiting and also the changes in the respiration, while the convulsions and increased reflex excitability point to the spinal cord.

The terminations of the motor nerves in voluntary muscles are paralyzed by aspidosamine and quebrachine in the frog, not by the other alkaloids; but all of them lessen the strength of muscular tissue and eventually paralyze it in these animals. Neither of these results has been observed to follow the injection of the alkaloids in mammals. Some anæsthesia has been observed from the local action of quebrachine on mucous membranes and nerve fibres.

The circulation in mammals is affected indirectly through the nausea, and large doses slow and weaken the heart through a direct action in addition; the blood-pressure falls from depression of the vasomotor centre. Under very large quantities the neuromuscular apparatus appears to be paralyzed, for adrenaline causes no rise in pressure. The ganglia on the course of the autonomic nerves are also weakened or paralyzed by these alkaloids in large

quantity. Even small quantities of quebrachine dilate the vessels of the skin and genital organs from action on the vessel walls (Müller). This causes erection and promotes sexual desire in both male and female animals, and this has led to the use of quebrachine (under the name of yohimbine) in veterinary medicine and also in man to improve sexual power in cases of neurasthenic impotence and similar conditions.

Some diarrhœa has been observed after the administration of these alkaloids, and this apparently arises from accelerated movement of the intestine (Cow). Diuresis is said to follow their use in some instances.

Some authors have observed a change in the red corpuscles under quebrachine, but its nature is unknown.

Commercial "aspidospermine" is a mixture of all the alkaloids along with other bodies. It is sometimes prescribed in doses of 1–2 mgs. ($\frac{1}{60}$–$\frac{1}{30}$ gr.).

Aspidosperma was advised by Penzoldt in the treatment of dyspnœa from a variety of causes, and his statements have received a certain amount of support from clinicians. The special conditions in which it has been advised are dyspnœa from pulmonary disease, especially emphysema, and from cardiac weakness and asthma. Its action on the respiratory centre may explain to some extent the benefits derived from it, but the increased secretion of the bronchi produced by the nausea may also be of some importance. The use of quebrachine in impotence has been mentioned already.

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XXX. QUININE.

The barks of various species of Cinchona and Remijia (Cuprea) contain numerous alkaloids which resemble each other in their chemical and pharmacological properties. The best known of these are *Quinine, Quinidine, Cinchonine* and *Cinchonidine*; the others, amounting to some twenty in number, are believed to resemble these in their effects on the organism, but very little has been done to determine this, and nothing is known regarding their relative activity.

The cinchona alkaloids are derivatives of quinoline. Cinchonine and cinchonidine are isomeric ($C_{19}H_{22}N_2O$), while quinine and quinidine, another pair of isomers, ($C_{20}H_{24}N_2O_2$) are methoxyl compounds of cinchonine.[1] These isomers differ in their optical activity, quinine and cinchonidine being lævorotary, while quinidine and cinchonine are dextrorotary; they are not complete mirror images of each other, however, as there are four asymmetric carbon atoms in each, and two of these appear to have the same sign of rotation in all these alkaloids.

1 The simplest of the cinchona alkaloids have the formula $C_{19}H_{22}ON_2$, comprising *cinchonine, cinchonidine, homocinchonidine* and *cinchonicine.* The others may be arranged in a series of growing complexity arising by comparatively slight structural changes. Dihydrocinchonines ($C_{19}H_{24}ON_2$)—*cinchotine* (*hydrocinchonine*), *hydrocinchonidine* (*cinchamidine*), *cinchonamine.* Hydroxycinchonine ($C_{19}H_{22}O_2N_2$)—*Cupreine.* $C_{19}H_{24}O_2N_2$—*quinamine, conquinamine.* Methoxycinchonine ($C_{20}H_{24}O_2N_2$)—*quinine, quinidine, quinicine.* Methoxydihydrocinchonines ($C_{20}H_{26}O_2N_2$) — *hydroquinine, hydroquinidine.* $C_{22}H_{26}O_4N_2$—*chairamine, chairamidine, conchairamine, conchairamidine.* $C_{23}H_{26}O_4N_2$—*cusconine, concuscamine, aricine.* Six or seven others are known, but their formulæ are less definite.

Cinchona bark contains besides these alkaloids several acids, including tannins, and some neutral substances.

The cinchonas are natives of Western South America, but are now cultivated in India and Java. It seems questionable whether the virtues of the bark were known by the native Indians before the invasion of the Spanish, and its introduction into medicine dates from about 1630–1640; its name bears testimony to its efficacy in the case of the Countess of Chinchon in 1638.

Action.—Quinine differs from most of the other important alkaloids in acting not on some specialized form of living matter, but on the general nutrition of almost all forms of protoplasm. Other alkaloids, such as strychnine, are also possessed of similar effects as regards nutrition, but their strong affinity for, and intense action on, some special tissue prevent their effects on the fundamental properties of living matter from being elicited in the higher animals. Quinine is therefore often termed a protoplasm poison because its action extends with but little variation throughout most forms of living matter. The effects of quinine on protoplasm generally consist in transitory augmentation of its activity, followed by depression and death.

The action of quinine on **Undifferentiated Protoplasm**, such as is found in the unicellular organisms and in the ovum, is therefore of greater interest than that of most alkaloids. Binz found that while very minute quantities sometimes increase the movements of the amœba and infusoria at first, large amounts paralyze them immediately, and the protoplasm assumes a darker granular appearance. The rhythmic movements of ciliated organisms are rendered slow and finally arrested by very dilute solutions, and the microbes of putrefaction are also acted upon by quinine, although they are more resistant than the protozoa; still, quinine solutions, 1 : 2000, delay the growth of bacteria. The alcoholic, lactic and butyric fermentations are similarly retarded, but it is apparently devoid of action on some of the lower forms, for moulds (Penicillium) grow freely in solutions of the salts, perhaps because the quinine fails to penetrate through the cell membrane. Another example of its action on the vegetable cell is that discovered by Darwin in some insectivorous plants (Drosera), in which the movements seem to be first excited and later paralyzed by the quinine salts.

The influence of quinine on the reproductive cells of animals has been carefully studied by O. and R. Hertwig, who found that both the spermatozoön and the ovum of the sea-urchin are injured by the addition of quinine to the sea-water, the movements of the former being paralyzed, and the stages preceding impregnation in the latter progressing more slowly, or actually retroceding. When quinine is applied after the male nucleus has entered the ovum, the complete conjugation is delayed and the whole process is rendered abnormal by the admission of several spermatozoa. Quinine applied still later prevents or delays the division of the ovum through its effects both on the nucleus and on the general protoplasm of the cell.

The individual cells of more complex organisms are affected in the

same way as these more simple ones. This was first demonstrated in the leucocytes by Binz, who showed that when quinine is added to a drop of blood under the microscope, the amœboid movements of the leucocytes are arrested, and they assume a spherical form, become darker in color and granular, and soon break up into débris. In the bloodvessels similar changes occur when quinine is applied locally, as to the frog's mesentery; the leucocytes again become darkly granular, and ceasing their creeping movements, are carried along by the current much more rapidly than usual. They are no longer observed to push their way through the vessel walls, and if they have already penetrated into the tissues their movements are arrested. If irritation be applied to the part, no such accumulation of leucocytes occurs in the tissues as in the unpoisoned animal, and if an irritant has been applied first and the leucocytes have poured out of the vessels before the quinine is applied, the process is arrested at once on its application. This poisonous effect on the leucocytes has received much attention, but only occurs when the alkaloid is present in a concentration of 1 : 3000, which is higher than can obtain in the blood of a living animal. More recent studies (Macnaughten) have shown that lower concentrations affect some other functions of the leucocytes, whose phagocytic powers are lessened by concentrations of 1 : 24,000; the bactericidal action of the plasms is also reduced by this concentration. There is no reason to suppose that this action on the white blood cells occurs when quinine is administered in therapeutic doses, which would not give rise to this concentration. All of these effects are greatly influenced by the reaction of the medium, since any increase in its alkalinity increases the toxicity; this may probably be ascribed to the alkaloid penetrating more easily into cells than its salts.

Some enzymes seem to be rendered inactive by quinine; for example, Binz states that the blood no longer forms the blue oxidation product of guaiac in the presence of quinine, but the alkaloid must be present in a concentration of 1 per cent. A number of other ferments act more vigorously in very dilute solutions of quinine, while they are retarded by larger quantities; for example, the autolytic ferment of the liver, pepsin, and rennet. And some appear to be much less susceptible to its action than others, for they are augmented in activity by quantities that retard or destroy those more readily affected.

The action on striated **Muscle** is similar to that on the lower organisms. There is sometimes a transient increase in its power but very soon the muscle contraction is weaker and fatigue follows more quickly than normally. Injections of large amounts of quinine salts into muscle kill the fibres and lead to sloughing.

The **Nerve Trunks** are said to be remarkably tolerant to solutions of quinine, which do not lessen their irritability when applied locally in sufficient quantity to cause marked abnormalities in the muscular contraction. In the frog, the terminations of the motor nerves in striated muscle are paralyzed by large doses, but not in mammals.

Unstriated Muscle in the mammals tends to contract under quinine, this action being especially marked in the **Uterus**, which is thrown into

strong rhythmical contraction when it is suspended in Ringer's solution containing quinine. Contractions are also initiated in the resting uterus when quinine is carried to it by the blood in the intact animal and this has led to its use in obstetrics to arouse the relaxed organ. Similarly the excised intestine suspended in Ringer's solution is aroused to increased movement by quinine, but there is no evidence that this occurs when quinine is carried to it by the blood. The spleen contracts however in the intact animal and in man, apparently from its acting on the muscle fibres, and quinine perfused through the arteries of an excised organ often narrows their calibre from contraction of the muscle of the walls; this contraction is often followed by relaxation. In each of these cases the action seems to be exerted directly on the muscle, which is first contracted and then relaxed if the dose is large.

The **Heart** is said to be sometimes accelerated in mammals, but is generally slowed and weakened when quinine is injected intravenously; this is due to direct action on the heart muscle, but large amounts may depress the vagus terminations. The heart continues to beat after the respiration has ceased in fatal poisoning. The weakness of the heart leads to a marked fall in blood-pressure. These cardiac effects are not observed except in a very slight degree when quinine is absorbed from the stomach even in large therapeutic doses. In the frog the heart is also slowed and weakened from depression of the muscle.

The **Central Nervous System** is found to undergo a slight and transient excitation, when large doses are injected in mammals, but the chief effects are of the nature of depression. Thus in the frog a short stage of slightly exaggerated reflex movement is followed by the loss of spontaneous movements, the arrest of the respiration, and paralysis of the spinal cord and ends of the motor nerves. In mammals, the spinal cord is stimulated by small quantities and then depressed. The respiration is sometimes quickened at first and later becomes weak and slow and its cessation is the cause of death. General depression and muscular weakness are usually the only cerebral effects observed in mammals and the tremor and convulsions which sometimes occur are perhaps due to the failure of the respiration.

The **Secretions** are not affected by quinine unless when very large quantities are injected into the glands, when they are arrested.

In **Man**, quinine taken by the mouth has the same action on appetite as the simple bitters. Ordinary therapeutic doses often produce no very obvious symptoms, the most frequently observed effect consisting in derangement of the **Sense of Hearing**, less frequently of that of **Sight**. Ringing or roaring sounds in the ears, accompanied by slight deafness, are produced by moderate quantities and large doses are not infrequently followed by complete loss of hearing for a time. Contraction of the field of vision is observed less often, but in some cases total blindness has been produced and has lasted for several days or even weeks. Color-vision is especially liable to be rendered imperfect or temporarily paralyzed by quinine; these disorders of sight are accompanied by a very

marked contraction and even obliteration of the retinal vessels and sometimes by degenerative changes in the retinal nerve cells and even by atrophy of the optic nerve. It is still undecided whether the vascular changes or the nervous degeneration is the primary lesion, but the majority of investigators at present favor the view that the constriction of the vessels is merely an accompaniment of the graver effects on the ganglionic structures. The symptoms in the ear have generally been regarded as the result of congestion and hæmorrhages in the tympanum and labyrinth, but Wittmaack has shown that this view is founded on erroneous observations, and states that degenerative changes occur in the spiral ganglion in the cochlea exactly analogous to those described in the retina. When quinine is taken continuously as a prophylactic, it is said to impair the hearing and sight permanently in some cases.

Quinine possesses some irritant action which betrays itself in discomfort in the stomach and eructation after large and repeated doses by the mouth, and by pain and tenderness when it is injected subcutaneously.

Large doses of quinine produce some confusion and depression with a sense of fulness and heaviness in the head from their action on the **Cerebrum**, and this is sometimes accompanied by uncertain gait and slow pulse. Very few cases of fatal poisoning have been satisfactorily determined to be due to quinine, although a considerably larger number have been attributed to it. In these cases marked weakness of the heart and collapse accompanied by loss of sight and hearing, muscular weakness, apathy, slow, gasping respiration and finally unconsciousness and total failure of the respiration were observed. In some cases delirium and convulsions have been noted. Enormous doses of quinine sulphate have been swallowed without any serious results. Thus in one case thirty grammes (one ounce) produced only some confusion and noises in the ears.

The extensive use of quinine in therapeutics has demonstrated that many persons have curious **Idiosyncrasies** in regard to it. This is betrayed in many cases by the development of ear symptoms after comparatively small doses, but in others symptoms arise which do not appear in the great majority of people even after large doses. The commonest of these are skin eruptions, of which a large variety have been described, and which can be distinguished from ordinary diseases of the skin only by the history or by the detection of quinine in the urine or in the stools. These exanthemata are often accompanied by some rise in temperature, which has received more attention than it appears to deserve, for it is rare and, even when present, is of insignificant extent. Other less important effects, which have been occasionally noted, are gastric discomfort and diarrhœa. In some cases the administration of quinine is followed by fever and hæmoglobinuria (black water) or albuminuria. The exact relation between quinine and this condition is a matter of dispute; blackwater fever occurs in sufferers from old malarial infection occasionally when no quinine has been given, but in many cases the symptom is provoked only by quinine;

on the other hand it often passes off when the treatment is continued. Quinine has no hæmolytic action except in quantities which would prove immediately fatal, and the blood of these black-water patients is not more readily laked by it than normal blood.

The **Uterus** is aroused to contraction by quinine, and abortion occurs occasionally after its use in malaria, while in other cases labor pains may be induced.

The **Blood** often contains fewer leucocytes after quinine in man and in animals. According to Roth a single dose generally causes leucocytosis at first, perhaps arising from contraction of the spleen. This is followed by a fall in the number of white corpuscles, especially of the lymphocytes, though the polynuclear cells are also reduced. The polynuclears then increase in number until a distinct leucocytosis is again present, but the lymphocytes remain reduced in number, while in the preliminary leucocytosis they predominate. Hæmolysis occurs only when quinine is present to the amount of 0.5 per cent., which is more than sufficient to arrest the heart.

The **Spleen** undergoes a marked diminution in size (Roth), presumably from active contraction of its muscular fibres. A similar constriction has been observed in the bronchi in animals.

The **Metabolism** is often said to be reduced by quinine, more especially that of the proteins, while the excretion of carbonic acid and the absorption of oxygen is universally stated to be unchanged. Careful experiments by Hardikar have failed to show any alteration in the protein metabolism either in man or animals under treatment with large doses of quinine. Under the older view quinine was believed to conserve the stores of protein in the body and to have a special value in wasting diseases and fevers from this "roborant "action.

Temperature.—Quinine has no significant effect on the normal temperature in man or in animals; it may reduce it by 0.1-0.2 degrees in some cases while in others its use is followed by a rise of similar dimensions. Its specific effects in preventing the rise of temperature in malaria are due to its destroying the parasite and not to any direct action on the mechanism which controls the temperature; until the parasite is destroyed, quinine is unable to reduce the body heat or even to prevent its rising. In other forms of fever, quinine not infrequently fails to reduce the temperature in man though it is sometimes successful in doing so. In animals large doses are found to lower fever temperature, but this is often accompanied by such symptoms as depression and muscular weakness, which in themselves would reduce the amount of heat formed and thus lower the unstable fever temperature.

This antipyretic action of quinine has been the subject of a number of investigations, which have given varying results. The general view is that in fever quinine reduces the heat production by lessening the heat formed, and this has been ascribed to its depressing the nitrogenous metabolism. But this view, which has always been vulnerable, has been rendered impossible by recent observations that quinine in quantities which reduce fever temperature in man and animals has no measurable action on the metabolism.

The only alternative explanation of the reduction of fever temperature by quinine is that the amount of heat lost by the body is increased by it in the same way as by the antipyretic series, under which heading the question will be discussed more fully. This change in the output of heat involves action on the temperature-regulating centre in the brain, and several early investigators found that quinine reduces the temperature when this centre is put out of action by section of the spinal cord. But in many of these experiments it appears that the possible action of large doses of quinine on the central nervous system and circulation was not taken into account sufficiently, and that some of the results which have been attributed to metabolic changes may have arisen from changes in these systems.

Further work is required to determine under what conditions and in what forms of fever the temperature falls under treatment with quinine, and it may then emerge that the action on the temperature is indirect as in the case of malaria.

Excretion.—Quinine appears in the urine within a short time (15 minutes) after its exhibition by the mouth, and it continues to be excreted by the kidney in some quantity during the next twenty-four hours, and in smaller amounts up to about seventy-two hours. Only about one-third of that absorbed appears in the urine, however, and only traces have been found in the other excretions, so that two-thirds or more undergoes complete destruction in the tissues. When quinine is injected into the subcutaneous tissues, some of it is deposited locally and only slowly redissolved, so that traces may be found in the urine for a week or more. When it is injected into the blood, it leaves the plasma within a few minutes, becoming attached to the corpuscles in some firm combination from which it is difficult to liberate it. It does not accumulate in any of the organs to any significant extent.

It is sometimes stated that a tolerance to quinine may be acquired by prolonged treatment, but this seems to be incorrect, the same symptoms occurring and the same amount appearing in the urine after prolonged administration.

Of the **Other Cinchona Alkaloids, Quinidine** resembles quinine closely in most respects. It has recently been employed for its effects on the heart, which appear to be similar to those of quinine in character, but are 5–10 times more powerful; The action is essentially a depression of the heart muscle, more marked in the auricle than in the ventricle, and manifesting itself in a reduction in the conductivity, and in a lower excitability in response to the natural impulses and to electric shocks; the refractory period is thus longer than before the quinidine. The strength of the contraction is sometimes increased to some extent, but this does not seem to be constant. In addition the ganglia on the course of the inhibitory impulses are weakened and this may lead to some acceleration of the beat sometimes; on the other hand this may be counteracted by the depression of the pacemaker in the sinus; the accelerator nerve is unaffected. In consequence of the reduced excitability, such irregularities as extrasystoles disappear under quinidine treatment and paroxysmal tachycardias from repeated extrasystoles in the auricle and ventricle also give place to the normal rhythm. Most important of all is its effect on auricular fibrillation, which can only be elicited with difficulty or not at all by electrical stimulation of the auricle under quinidine. Simi-

larly in man, auricular fibrillation may be arrested by the use of quinidine. The depression of the heart is attended by a marked fall in the blood-pressure in animals; possibly there may also be dilation of the arterioles, but this is still uncertain. Hydroquinidine acts on the heart in the same way and in about the same strength as quinidine.

Cinchonine, while very similar to quinine in most points, has some tendency to produce convulsions, but this effect is much more liable to occur under **Cinchonidine**, which, save for its resemblance in other features to quinine, would be entitled to be classed among the convulsive poisons. These convulsions are of an epileptiform character, and are only produced by very large doses, but even small quantities administered to epileptics increase the number of the attacks. These epileptiform seizures are not prevented by the removal of the cerebral cortex in dogs, and the irritability of the motor areas is not altered by cinchonidine, so that some lower division of the central nervous axis appears to be the seat of action in these animals; but in man the more highly developed cerebral cortex is also involved. **Cinchonamine** possesses an even more marked convulsant action than cinchonidine.

The effects of the other alkaloids have not been the subject of much investigation, but they seem to differ from quinine chiefly in their effects on the central nervous system. These are not entirely absent in quinine itself, for, as has been stated already, the reflex irritability is at first increased and then diminished in both frogs and mammals, and in some cases even convulsions are stated to have occurred in quinine poisoning.

Many artificial derivatives have been formed from the cinchona alkaloids, but few of them have been examined pharmacologically. *Optochin* or *ethylhydrocupreine*, one of these derivatives which has been used in therapeutics, appears to differ from quinine only in slight measure in its general action, but is more liable to induce blindness. *Cupreine*, obtained from Remijia, has been used experimentally, but has not proved of therapeutic value.

Preparations.

U. S. P.—**Cinchona**, the bark of Cinchona Ledgeriana and C. calisaya and of hybrids of these and of other species of Cinchona, yielding not less than 5 per cent. of total alkaloids. Dose, 1 G. (15 grs.).

Cinchona Rubra, red cinchona, the bark of Cinchona succirubra, containing at least 5 per cent. of alkaloids. Dose, 1 G. (15 grs.).

Fluidextractum Cinchonæ contains 4 per cent. of alkaloids, 1 mil (15 mins.).

Tinctura Cinchonæ contains 0.9 per cent. of alkaloids, 4 mils (1 fl. dr.).

Tinctura Cinchonæ Composita is the only preparation of red cinchona, and contains in addition serpentaria and bitter orange peel. 4 mils (1 fl. dr.).

Quinina, Quininæ Sulphas, *Quininæ Bisulphas*, *Quininæ Dihydrochloridum*, Quininæ Hydrochloridum,	0.1 G. (1½ grs.) as tonic. 1.0 G. (15 grs. or more daily in malaria.

B. P.—**Cinchonæ Rubræ Cortex**, red cinchona bark, the dried bark of the stem and branches of Cinchona succirubra. It ought to contain 5–6 per cent of total alkaloids, of which one half should consist of quinine and cinchonidine.

Tinctura Cinchonæ, 1 per cent. of alkaloids, ½–1 fl. dr.

Tinctura Cinchonæ Composita, containing bitter orange peel, serpentary and coloring matters, ½–1 fl. dr. (2·4 c.c.)

Quininæ Hydrochloridum, *Quininæ Hydrochloridum Acidum*, Quininæ Sulphas,	1–10 grs.(0.06–0.6 G.).

The preparations of cinchona were formerly much more in vogue than at the present day, in which they have been replaced for most purposes by the

alkaloids. They are still prescribed alone or together with other remedies as stomachic bitters.

Quinine is practically insoluble in water and several of its salts are only dissolved sparingly. Thus, the sulphate requires 800 times its own weight of water, the hydrochloride 35, and the hydrobromide 40. The presence of acid in excess renders them much more soluble, and the acid hydrochloride or dihydrochloride is dissolved in less than its own weight of water, the bisulphate in 10 parts. They all form crystalline powders with a very bitter taste, and their solutions in water have a blue fluorescence when sulphuric acid is present. The acid hydrochloride and the bisulphate have an acid reaction, the others are neutral.[1]

The hydrochloride of quinine is the most soluble of the salts and is therefore preferable to the others; the sulphate is frequently prescribed, the hydrobromide and salicylate seldom. Instead of the acid salts being prescribed, some sulphuric acid or hydrochloric acid may be ordered to be added to the neutral salts in order to facilitate their solution.

The salts of quinine are frequently given in the form of pills, cachets, tablets, or capsules, which have the advantage of avoiding the bitter taste, but from which the alkaloid is more slowly absorbed than from solutions. Care must be taken that the pills are soft and freshly prepared, as when kept for any length of time they become hard, and in this condition frequently pass through the bowel unabsorbed. The salts or the pure alkaloid may also be given as powders, or the former in solution, but these are objected to by many patients on account of the bitter taste. When rapid absorption is desired, solutions should be used, flavored, if necessary, with syrup and volatile oils. Solutions of the salts are occasionally injected as enemata, but are liable to set up irritation and to be rapidly evacuated. Intramuscular injection has also been advised in cases of emergency, or where the salt cannot be retained or absorbed from the stomach; this form of medication is painful, but does not seem to induce more serious results if ordinary care is used. The neutral hydrochloride may be dissolved in 5–10 times its weight of hot water and injected when the solution reaches the body temperature with less pain than is elicited by other salts; or the acid hydrochloride or bisulphate may be used but causes more pain. Subcutaneous injection of quinine salts, especially the acid ones, is very painful and has sometimes been followed by sloughing. The intravenous injection of quinine has been practised with success in cases of pernicious malaria; the hydrochloride dissolved in a solution of common salt is slowly injected into one of the veins of the arm; a marked fall of blood-pressure may follow too rapid injection of quinine from its poisonous action on the heart, and large doses (15 grs.) may induce symptoms even if injected slowly.

Many other salts of quinine have been proposed and have enjoyed a certain reputation for some time. Among the better known of these is the *tannate* (U. S. P.) which is exceedingly insoluble, has little taste, contains 30 per cent. of quinine and is prescribed in powder in doses of 0.2 G. (3 grs.). Other salts which have been recommended are the *tartrate* and the *lactate*. *Euquinine* is the very insoluble ethyl-ester of quinine-carbonic acid ($CO(OC_2H_5)(OC_{20}H_{23}N_2O)$) and possesses the therapeutic virtues of quinine with a less bitter taste. *Aristochine* ($CO(C_{20}H_{23}N_2O)_2$) and *Chinaphenine* ($CO(NH.C_6H_4.OC_2H_5)(OC_{20}H_{23}N_2O)$) are less satisfactory compounds of quinine of a similar nature. All three preparations are prescribed in powder or tablets, in the same dose as quinine.

A famous preparation of quinine is *Warburg's tincture*, which has been extensively used in India in the treatment of malaria. It contained a very large number of ingredients, many of which were certainly entirely superfluous Among the more important constituents were aloes, rhubarb, gentian, camphor,

[1] A double salt, the hydrochloride of quinine and urea, has been advocated, but in solution it forms free urea and the acid hydrochloride of quinine, over which it has no advantages; it is strongly acid and irritant and though this is partly relieved by its anæsthetic action, it is not more efficient in this respect than the other salts.

and various volatile oils; it is possible that some of these may have aided the quinine through their effects on the stomach. Various drugs, such as capsicum and piperine, have long had some reputation as adjuvants in quinine treatment for a similar reason.

The other alkaloids have been used occasionally as substitutes for quinine, and MacGilchrist has carefully compared their efficiency in malaria. He finds that hydroquinine is rather more effective than quinine, cinchonine and quinidine, while cinchonidine is the least useful of the cinchona alkaloids; optochin was also of little value.

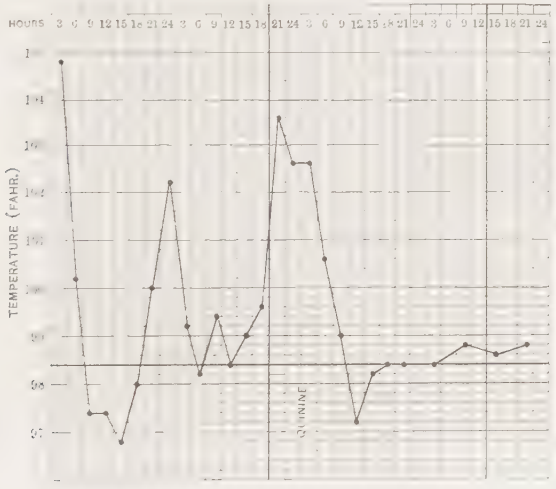
Therapeutic Uses.—The introduction of cinchona into therapeutics was due to the discovery of its efficacy in ague or **Malaria**, and with growing experience in the disease and its treatment, the confidence in the drug, or rather in its chief alkaloid, has constantly increased, until the action of quinine in malaria is now quoted as the best example of a specific in therapeutics. The explanation of its action was only reached when Laveran discovered the parasites of malaria, although in 1868 Binz suggested that the then unknown malarial poison was probably rendered inert by quinine. Malaria is now known to be due to three distinct parasites, which harbor in the red-blood corpuscles and multiply there, and then issuing from the cells in immense numbers invade new corpuscles. When the spores break out of the red cells, there is a sharp attack of fever, which passes off when they have reached the interior of new corpuscles, but returns when a new swarm of spores is liberated. The fever thus recurs at regular intervals in the simpler forms of malaria, but may be rendered irregular by double or multiple infections. The parasites of malaria belong to the group of the protozoa and are thus nearly related to the amœba on which Binz made his observations, and also to the organism of amœbic dysentery and of syphilis.

The organisms of malaria are most susceptible to quinine when they are in the free state in the plasma, though the less dangerous forms are also destroyed after they have reached the shelter of the corpuscles. In the more malignant form of infection, the parasites in the corpuscles are apparently not affected by quinine and can only be got rid of by preventing them from being reinforced by new broods. It is therefore of the first importance to supply quinine to the blood at the period at which the spores are liberated. When quinine is given at the appropriate time, the organism breaks up and disappears, but a few more resistant forms may escape and multiply until they are numerous enough to provoke another paroxysm of fever; the treatment is therefore continued until all the parasites have succumbed.

In a drop of malarial blood the plasmodia may be seen in active movement, but a minute drop of quinine solution paralyzes and kills them, exactly as it kills the common protozoa found in water, the only difference being that the malarial organism is infinitely more susceptible to its action; this greater susceptibility does not arise from the presence of the blood plasma, for other organisms in the human blood do not succumb to quinine, and one which occurs in bird's blood and resembles the plasmodium malaria closely, is not materially injured. The malarial organism appears to be acted on specifically by quinine, that is more

strongly than other living cells, and the alkaloid can consequently be introduced into the human body with impunity in doses which are destructive to the simpler organisms which have invaded it. Experience has shown that quinine is most effective when it can act during and immediately after the paroxysms, and this is now explained by the fact that the organisms are in their least resistant form—the amœboid—at this time. If quinine is given three or four hours before an attack, sufficient will remain in the blood when the temperature begins to fall to destroy the unprotected spores of the parasite, or the same result may be obtained by a dose given as the temperature begins to fall, provided the drug is rapidly absorbed, as is ordinarily the case. It may be ordered in one dose of about 1 G. (15 grs.), or in divided doses given at

FIG. 65



Temperature chart in a case of malaria in which quinine (10 grains) was administered in the third paroxysm as the temperature was falling. On the following day no rise of temperature occurs. The temperature was taken every three hours. (Dock.)

intervals during the fall of the temperature. This frequently prevents the next attack, but some of the organisms survive and the treatment should be continued for a month, beginning with 5 grains three times a day and gradually reducing the dose to 3 grains. In the severer forms of infection larger doses are necessary, and 5 grains every four hours may be necessary during the first week. Some authorities recommend that instead of this continuous administration, single large doses (15 grs.) should be given at intervals so timed as to supply the drug at the moment of sporulation, but this is not so generally successful as the continuous treatment.

Much difference of opinion exists as to the details of the treatment, but most methods are successful in relieving the immediate attacks, while none of them can be relied upon to avert relapses in a considerable

percentage of cases. The general impression is that benign tertian malaria is more amenable than the other forms, but Acton holds that quinine is more successful in malignant tertian in which the treatment is seldom followed by relapses, while quinidine is more efficient in the benign form; there is need for further comparison of the different alkaloids of cinchona.[1]

Quinine is generally administered by the mouth in malaria, but its intensely bitter taste renders this treatment disagreeable, and in children and in cases of persistent vomiting it may be impossible; in children quinine tannate or euquinine may be employed, and in severe vomiting or other emergencies a soluble preparation is injected into the muscles. In severe infection, quinine may be given intravenously in 15-grain doses repeated if necessary after six hours; for this purpose the hydrochloride dissolved in warm saline is the best preparation, the more soluble acid salts tending to react with the blood proteins. A great deal of weight was formerly laid on the use of purgatives and emetics as preliminaries to the treatment of malaria with quinine, and the former are undoubtedly of service sometimes, although it is unnecessary to delay the quinine treatment by waiting for the intestines to be evacuated. Special sensitiveness to quinine may render the treatment of malaria difficult; for example, small doses may be followed by severe effects on the hearing in some patients; in these cases bromide often relieves the symptoms when given in adequate doses. Again, the digestion may be much disturbed and it may be necessary to commence the treatment by an intravenous injection of the hydrochloride. Hæmoglobinuria following quinine indicates that the dose should be reduced. Pregnancy is not a contra-indication but suggests that small doses should be used.

Quinine is used not only as a remedy, but also as a prophylactic against malaria. Its value for this purpose has been attested by long experience, but there is still no unanimity of opinion as to the best method of administration and the dose required. Thus Koch advised 15 grs. to be taken on two consecutive days every week or ten days, others suggest 8 grs. every fourth day, while a common prophylactic treatment is to take 3–5 grs. daily and 10 grs. once a week. Quinine is best taken after meals, when it disturbs the digestion least. The malarial organisms do not acquire tolerance to quinine, and the prophylactic use of the drug thus does not impair its value in the treatment of an infection.

One of the results of quinine medication in early cases of malaria is the reduction of the enlarged spleen, and this has led to its use in other **Diseases of the Spleen** with enlargement. In malaria the effect on the spleen is only secondary to the removal of the cause of the disease, but the action of quinine in contracting the muscle fibres of the spleen may explain its being of benefit in other splenic disorders. In

[1] Several other alkaloids were formerly suggested as substitutes for quinine in malaria; thus berberine and buxine had formerly some reputation, and harmine (from Peganum Harmala) has recently been subjected to trial, but none of these has proved to possess the curative power of quinine, although they all have some effect in the disease.

some cases of leucæmic enlargement encouraging results have been obtained from the continued use of quinine.

Various other **Febrile Conditions** have been treated with quinine, partly for the sake of its antipyretic effects and partly in the belief that it acts as an antiseptic in the blood. As regards its effect on the temperature in non-malarial fever, it does not reduce it so rapidly or to the same extent as its rivals of the antipyrine group, but may maintain it at a low point for a longer time; the unpleasant effects on the brain and hearing further limit its use. The use of quinine in non-malarial cases has been based in part on the belief that it lessened the tissue waste, which has now been proved to be erroneous. So that it is now being confined more and more closely to combating malaria, and in other forms of fever antipyrine and its allies have succeeded in ousting quinine from its former position as the best of the antipyretics. The use of quinine has been recommended in septicæmia, largely from a belief in its antiseptic action in the blood. In this connection it is to be remarked that the microbes of septic fever are much more resistant to the action of quinine outside the body than are the protozoa, and the question therefore arises whether the blood and tissues are not liable to be seriously injured by the quantity of quinine required to act on the parasites they contain. In many cases of septicæmia in which beneficial results are said to have been obtained by the use of quinine, the quantity administered was obviously too small to have any effect either on the temperature or on the microbes.[1]

Quinine has been used in various forms of **Neuralgia and Headache**, but has been replaced by the antipyrine series and especially by acetylsalicylic acid for these conditions.

The tinctures of cinchona are often prescribed as **Stomachic Bitters**, and for this purpose are generally fortified by preparations of nux vomica or of the simple bitters.

Quinine has been advised in whooping-cough, hay fever and influenza, and in fact is regarded by many as a specific in these diseases, though others have found it unreliable. It is often difficult to induce a child to take the bitter salts, and recourse may be had to the alkaloid itself, euquinine, or the tannate disguised with sugar or chocolate. The use of a solution as a wash for the nose in hay fever was brought into prominence by Helmholtz, who gained relief in this way, but it has not proved very efficacious. The local use of quinine solutions and of cinchona preparations is also advised in relaxed throat (gargle) and in gonorrhœa (urethral injection). It has sometimes been used as an antiseptic externally, but is too expensive.

[1] Morgenroth has found that ethylhydrocupreine, a derivative of cupreine differing from quinine in the presence of ethoxyl instead of methoxyl, has a well-marked beneficial action on mice infected with pneumococcus and that its previous injection protects these animals from infection. It does not appear to have any such remedial action in pneumonia in man and has not been definitely shown to improve the prognosis. Moore and Chesney found, however, that the serum of patients treated with this drug has definite bactericidal powers. Severe and even fatal poisoning has occurred from the intravenous injection of less than a gram of ethylhydrocupreine (Optochin) in man.

Quinine has been advised as an **ecbolic** to increase the contractions of the uterus during labor. This was suggested by the observation that in malarial regions, abortion occasionally occurred after quinine, and satisfactory results are reported from the treatment of uterine inertia with one-gramme doses of quinine; the action is the same as that under pituitary preparations, which are more commonly employed for this purpose at the present time.

Quinine has been advocated as a **local anæsthetic**; the quinine and urea hydrochloride has been used chiefly, but is strongly acid in reaction and the neutral hydrochloride of quinine in 0.5–1 per cent. solution is preferable for injection, while stronger solutions may be applied to the throat and some other mucous membranes. It differs from cocaine in inducing anæsthesia more slowly and still more in maintaining it for many hours or even days. It has been advised to wash painful wounds after operation, to relieve after-pains, to spray the throat and for many other purposes. Its toxicity after absorption is very low, but it injures the tissues locally and delays healing.

Quinidine Sulphate has been used recently as a cardiac depressant to combat the exaggerated excitability seen in **Auricular Fibrillation and Flutter, Extrasystoles** and other forms of heterotopic rhythm; in about 50 per cent. of the cases of auricular fibrillation thus treated, the normal rhythm is restored for a longer or shorter time. When the effect of the treatment is watched by means of the electrocardiograph, the oscillations of the auricle are seen to become progressively slower and coarser, while the rhythm of the ventricle generally quickens; then the fibrillation is suddenly replaced by normal movements of a rapid rhythm and this in favorable cases passes into regular beating of auricle and ventricle at 70 to 80 beats per minute. The effects are quite different from those under treatment with digitalis, which does not arrest the fibrillation but protects the ventricle from the auricular impulses; under quinidine, the abnormal activity of the auricle ceases from the depressant action of the alkaloid. Quinidine sulphate is generally given by the mouth in doses of 0.4 G. three or four times a day, or 0.2 G. every two hours, and the treatment is not continued if it is not successful, but if the normal rhythm is restored smaller doses of quinidine given for a few weeks may help to maintain it; otherwise many cases may relapse into fibrillation again. The treatment must be controlled, and at present this is best done by the electrocardiograph. The pulse accelerates as the auricle is slowed and this may become alarming; if digitalis is given for a few days before the quinidine, the quickening of the pulse is smaller. The restoration of the normal rhythm is not free from danger, for during fibrillation the auricle forms a backwater in which clotting may occur, and when it resumes its normal beat under treatment, the expulsion of the clot may lead to fatal embolism. Nausea, headache and discomfort from the sounds in the ears may be complained of under the treatment.

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XXXI. THE ANTIPYRETICS. (ACETANILIDE AND ANTIPYRINE SERIES.)

The antipyretics are a recent addition to therapeutics, the oldest of this group now in use dating only from 1884. Up to 1875 the only means of combating high temperature were baths, vegetable alkaloids, such as quinine, or alcoholic preparations, but in that year Buss discovered that salicylic acid produces a fall in the fever temperature, and soon afterward carbolic acid and resorcin and its isomers were employed as antipyretics. A very large number of antipyretics have been introduced since that time, but most of them have had only a temporary vogue, and those in general use at the present time are comparatively limited in number.

Quinine is a quinoline derivative, and quinoline itself, as well as some of its simpler compounds, were among the earlier antipyretics suggested. *Quinoline* (C_9H_7N) was soon found to be dangerous from its producing collapse, but its derivatives *Kairine* ($C_9H_9(OH)N—C_2H_5$), *Kairoline* ($C_9H_8(CH_3)(OH)NH$) and *Thalline* ($C_9H_9(OCH_3)NH$) were used extensively, although they have now been entirely abandoned; *Analgen* is a quinoline derivative, still prescribed to a very limited extent.

A new antipyretic was introduced in 1884 under the name of **Antipyrine** or **Phenazone**, which is derived from phenylhydrazine, and has proved superior to all of the earlier drugs. *Phenylhydrazine* ($C_6H_5—NH—NH_2$) produces a fall in the fever temperature, but this is frequently accompanied by collapse and changes in the blood, which prevent its use in medicine. Several of the simpler compounds have received a more or less extensive trial as antipyretics, but have proved dangerous and inferior to *Antipyrine*, phenyldimethylpyrazolon,

$$C_6H_5N\begin{cases}NCH_3—C(CH_3)\\ CO—CH\end{cases}$$

which is still largely used as an antipyretic, either in its original form or as a constituent of numerous combinations which have been introduced of late years. Among these may be mentioned *Pyramidon* (dimethylamino-antipyrine), *Hypnal* (chloral and antipyrine), *Salipyrine* (salicylic acid and antipyrine).

Antipyrine early found a rival in **Antifebrine** or **Acetanilide,** which was advised as an antipyretic in 1886 by Cahn and Hepp. *Aniline* ($C_6H_5NH_2$), from which it is derived, has also some action on the temperature, but like phenylhydrazine produces dangerous collapse and destruction of the blood cells. *Acetanilide* ($C_6H_5NHCOCH_3$), the first of its derivatives to be introduced, is not entirely devoid of this poisonous action, and has been supplanted to a considerable extent by more complex and less poisonous bodies. It was soon found that both aniline and acetanilide undergo a partial oxidation in the body, with the formation of amidophenol or its derivatives, and the belief that the antipyretic effects were due not so much to the original substance as to these oxidation products led to the introduction of numerous derivatives of paramidophenol ($NH_2-C_6H_4—OH$). This body has antipyretic properties but suffers under the same disadvantages as aniline. Among its derivatives the most satisfactory antipyretics are those in which the hydrogen of the hydroxyl is substituted by alkyl, while an acid radical is added to the amido-radicle. The first of its compounds to be introduced was **Phenacetine** ($COCH_3NH—C_6H_4—OC_2H_5$) which differs from acetanilide only in the addition of ethoxyl in the para position. It is less dangerous than acetanilide and antipyrine, and has therefore been largely used, and has been followed by other bodies which are identical with it, except in the acid radicle attached to the nitrogen. Among these phenetidines may be mentioned *Lactophenine* (lactyl-phenetidine), *Triphenine* (propionyl-phenetidine), *Malakine* (salicyl-phenetidine), and *Salophen,* which contains similar constituents, *Citrophen* (citryl-phenetidine), *Kryofine* (methylglycolic-phenetidine), and *Phenocoll* (glycocoll-phenetidine), with its compound with salicylic acid, *Salocoll.*

Several urethane derivatives have also received a trial as antipyretics, among them being *Euphorine* (phenylurethane), which is somewhat poisonous, and *Thermodine* (phenacetine-urethane).

With the exception of antipyrine, all the antipyretics at present in use probably owe their activity to the formation of simple derivatives of paramidophenol in the tissues, and differ chiefly in the rapidity with which this decomposition occurs; when it is quick, it is followed by destructive blood changes and a tendency to collapse, while the antipyretic effects pass off soon. Those drugs are found the most satisfactory antipyretics in which the decomposition proceeds gradually, so that the temperature falls slowly and remains low for a longer time. The simpler antipyretics, such as acetanilide, have given way largely therefore to the phenetidine compounds.[1] Among these it is impossible to determine the most suitable, but none of them has been proved to be superior to phenacetine. Where the merits seem so equally divided, it is perhaps more important to learn to use one with judgment than to hurry after each new product without sufficient experience of its predecessor.

Symptoms.—The effects of the antipyretics vary not only with the dose but with the individual patient. Many persons can take very large doses without apparent effect, while in others comparatively minute quantities produce symptoms of greater or less importance The

[1] For a detailed discussion of these principles see *V. Mering*, Therap. Monatsh., 1893, p. 577, and *Hinsberg and Treupel*, Arch. f. exp. Path. u. Pharm., xxxiii, p 216.

effects are not always the same, even in one individual under the same dose of the antipyretic, and it is impossible to state at present what are the conditions that involve the peculiar train of symptoms. A very large number of disorders have been attributed to the antipyretics in man, but it is impossible to consider any here except those more commonly observed. Among these are *skin eruptions* of various forms, such as red, erythematous, itching patches or more widely diffused hyperæmia resembling the onset of measles or scarlatina; urticaria occurs not uncommonly, while eczema and bullæ are rarer. In some cases an œdematous swelling has been observed. Some *fever* occasionally accompanies the eruption and renders the diagnosis from the infectious exanthemata even more difficult. These skin affections seem to be elicited more frequently by antipyrine than by acetanilide and the phenetidine compounds. They have been attributed to dilatation of the cutaneous vessels, but this in itself is insufficient to explain their appearance, although it may be a favoring condition. Profuse *perspiration* not infrequently follows the use of the antipyretics in fever, and if the fall in temperature is rapid, and the action of the drug passes off soon, the subsequent rise of temperature may be accompanied by *shivering and rigor*, but these symptoms are scarcely to be looked upon as direct effects of the drug, but rather as resulting from the rapid changes in temperature. They are produced much more frequently by the older and simpler antipyretics than by those of more recent introduction.

Sometimes *catarrh*, burning and swelling *of the throat* and *mouth* are observed after antipyrine, and more rarely *nausea* and *vomiting*. *Cerebral symptoms* are rarely elicited beyond slight dulness, confusion or apathy. Alterations of the hearing similar to those described under quinine have been observed in some cases. More serious symptoms are those of *collapse*, which are sometimes induced by acetanilide. In the milder cases the skin is cool, the pulse is rather small and rapid, and some anxiety and alarm is felt by the patient, but the condition passes off in a short time. In more severe cases the skin is cold and covered by a clammy perspiration, the heart is weak, irregular and sometimes fluttering, the temperature may be subnormal and the pupils are slightly dilated. The patient may be conscious, fainting may occur, or an apathetic, confused condition may be produced. The weakness of the heart is the chief source of anxiety, and the total failure of the circulation seems to be the cause of death. These cases of collapse occur more frequently when a rapid fall of temperature has been produced than under other circumstances, but may be observed in cases in which no fever has been present.

Marked *cyanosis* occurs sometimes under acetanilide and the earlier members of the series, very rarely under antipyrine and the phenetidine compounds. It arises from the formation of methæmoglobin in the blood, and when this is accompanied by collapse, the cyanosis may be very intense. It is often accompanied by dyspnœa and acceleration of the pulse, and it lasts for a varying length of time, sometimes passing off in a few hours, at other times persisting for several days.

Occasionally a certain *tolerance* is gained, and larger doses of the antipyretics are required to produce effects than were necessary at the beginning of the treatment. Many cases of *chronic poisoning* are recorded from the habitual use of acetanilide. The symptoms consist in disturbance of the digestion, cyanosis, tremor, muscular weakness and general mental debility; the blood is often chocolate-colored from the formation of methæmoglobin, and the urine often contains hæmoglobin, or its products, or may be colored by the oxidation products of paramidophenol. The condition is sometimes difficult to recognize, especially as the patient may deny that the drug has been taken. The symptoms disappear rapidly when it is given up.

These drugs are by no means very poisonous, normal animals showing no reaction to doses which are sufficient to cause marked changes in fever. In the frog **Antipyrine** causes an increase in the reflex irritability, which sometimes leads to tetanic convulsions and is followed by depression, loss of the voluntary movements, and eventually by complete paralysis and death. In mammals its injection is followed at first by a period of quiet and sometimes of somnolence, which is said by some authors to occur also in the frog previous to the increase in the reflex irritability. Some rise in the reflex irritability may be made out in the mammal at this stage, and large doses cause convulsions and tremors, and subsequently unconsciousness and collapse, ending in complete paralysis. The pulse is accelerated by small doses, while in the later stages of poisoning it may be slow, and some dilatation of the skin vessels and flushing have been observed. The respiration is at first accelerated, and then becomes slow and irregular when large doses are injected. In dogs vomiting and dilatation of the pupil generally occur.

Acetanilide is more poisonous than antipyrine in both frogs and mammals, but resembles it in its general effects, producing first a more or less marked stage of lessened activity, followed by convulsive movements. The respiration is not so much accelerated as by antipyrine, and, according to some observers, is slow from the beginning of the action. The heart is first accelerated and then slow and irregular, and cyanosis and collapse are more frequently observed than under antipyrine. **Phenacetine** and its allies are much less poisonous than the two foregoing, but in large quantities produce almost identical effects—somnolence followed by convulsions, cyanosis, and collapse symptoms, first rapid, then slow respiration and heart. **Lactophenine** is said to have a more sedative effect than the other antipyretics, and to induce complete narcosis in the rabbit.

Action.—The action of these drugs on the various organs is very imperfectly understood. The **Nerve Centres** are affected, as is shown by very slight somnolence occasionally in animals and also in man, but much more frequently by the relief of pain as in neuralgia and headache; Martin, Grace and McGuire state that after phenacetine the general sensitiveness of the body may be shown to be lower by measurements of the threshold sensibility of the skin. This is generally attained without any observable depression of mental activity and is therefore quite distinct from the analgesia obtained by the use of morphine or anæsthetics. This suggests that the antipyretics relieve pain by affecting not the cerebral cortex, but some lower point, which may be assumed to be a synapse on the path conveying pain sensations; there are two of these, one in the spinal cord and one in

the thalamus, and as the antipyretic action of this group is due to changes in the neighborhood of the latter, it seems likely that their action in abating pain may be located here also (Head).

Most of the antipyretics increase the excitability of the spinal cord at first, and this may lead to convulsions in the frog. The origin of the convulsions in mammals is still somewhat doubtful; in general, they seem to be of cerebral origin, but when large quantities are injected they are seen even when the spinal cord is divided from the brain, so that the cord appears to be thrown into a condition resembling that discussed under strychnine poisoning. In considering the cause of these convulsions perhaps too little weight has been laid by some writers on the changes in the blood, respiration and circulation, for it is possible that the convulsions in some cases are asphyxial in character, and not due to the direct action of the poisons on the brain.

In ordinary poisoning the peripheral **Nerves** and nerve ends do not seem to be seriously involved, and the final paralysis in both frogs and mammals is undoubtedly central. Santesson found that antipyrine tended to increase the power of the frog's **Muscles**, and several observers have noted that the nerves and motor terminations are paralyzed by the direct application of this drug. Antipyrine has some effect as a local anæsthetic when applied to the mucous membranes.

The **Heart** in the frog and mammals is first accelerated and then slowed by the antipyretics in general, these alterations being entirely independent of the inhibitory mechanism and due to a direct effect on the cardiac muscle. The increased rhythm of the heart leads to a slight rise in the blood-pressure, which sinks again as the pulse becomes slower. There is no satisfactory proof that the vaso-motor centres are involved in the rise of pressure, although it is not unlikely that they undergo a primary stimulation at the same time as the respiratory centre.

Most of this series, except antipyrine and its compounds, tend to cause alterations in the **Red Blood Cells** when they are given in large quantities. This action is manifested especially by the simpler bodies of the series, and is still more marked in poisoning from aniline, phenylhydrazine, paramidophenol or quinoline. On the other hand, most of the phenetidine compounds produce it much more rarely, and antipyrine seems devoid of this action. The alteration consists in the formation of methæmoglobin, which may be readily detected by its characteristic spectroscopic appearance. Small quantities of the antipyretics cause its formation within the blood-cells, which remain intact, but larger doses, especially of the more poisonous members, destroy the red-blood cells and free the methæmoglobin in the plasma. In the blood various distorted, shrunken red cells may be observed, often entirely devoid of coloring matter, while part of the methæmoglobin escapes through the kidneys, and nephritis occurs in some cases with albumin, hæmoglobin and even blood in the urine. This effect on the blood arises from the decomposition products of the antipyretics, such as a hydroxylamine product ($C_6H_5NOH.COCH_3$) from acetanilide, and perhaps paramidophenol or the corresponding quinoline derivatives

from others; this decomposition proceeds more slowly in phenacetine and its allies and is absent after antipyrine, which explains the rarity of the symptoms after these drugs; it only occurs in the tissues and no methæmoglobin is formed when the antipyretics are added to drawn blood.

All of the antipyretics have some **Antiseptic** action, which varies in the different members with their solubility and stability. Antipyrine is found to preserve blood from putrefaction for some days when added to it so as to form a solution of 2–5 per cent. Watery solutions of this strength destroy protozoa and stop the movements of the leucocytes.

The action of the antipyretics on the **Metabolism** of healthy men and animals has been the subject of a number of investigations which have given by no means uniform results, especially in regard to the nitrogen elimination. *Antipyrine* has no influence, or only an insignificant one, on the metabolism of the healthy tissues, whether this is measured by the nitrogenous excretion or by the gaseous exchange in the lungs.

Acetanilide, on the other hand, has a distinct effect on the nitrogen eliminated, although this is only elicited by large doses. After ordinary quantities the urea and total nitrogen of the urine may be slightly augmented, but in large doses acetanilide causes an increase of 30–35 per cent. in these, which indicates a large increase in the tissue waste. The *other antipyretics* have not been examined so carefully. The exchange of gases in the lungs is not affected by the antipyretics in healthy animals, and no definite change has been observed in the excretion of uric acid.

The specific effects of the antipyretics on the **Temperature**, while recognized by all, have been the subject of endless discussion, owing to the complex mechanism through which they are elicited. In the normal animal the temperature is but little altered, except by doses large enough to produce collapse, but when it is abnormally high, as in fever, the antipyretics cause a fall of greater or less extent.[1] This fall in temperature occurs at varying intervals after the ingestion of the drug, but, except in refractory cases, always begins within two to three hours. Its extent varies, the temperature in some cases reaching the normal or even a subnormal point, while in others the change is insignificant. Continuous fever without any natural rise and fall is much less affected, as a general rule, than one with alternate rise and fall of the temperature, and in the latter form the result is greater if the drug is given at the beginning of one of the natural remissions.

The fall in temperature is often accompanied by flushing of the skin and perspiration. The oxygen absorbed and the carbonic acid

[1] This difference in the reaction of normal and fevered animals has aroused much interest. It may be an example of a general law for which some evidence is available, that it is easier to reduce an abnormal organ or function to its normal condition, than to change a normal one to unusual activity or inactivity; a definite rate of function is the habit of each organ and it moves away from this normal with difficulty and returns to it with readiness.

excreted are lessened, and the urea and nitrogen of the urine are also diminished after antipyrine, while they are not infrequently increased after acetanilide, especially when administered in large quantities.[1] The heart is often reduced in rate, and the pulse improves in strength, but these changes are due to the fall in the temperature and not to the direct action of the drugs. Some remedies owe their antipyretic properties to their increasing the secretion of the sweat glands, but although perspiration not infrequently occurs during the fall of temperature under the new antipyretics, this is merely a secondary result here, for when the perspiration is checked by atropine, the fall of temperature proceeds uninterruptedly.

The temperature in healthy warm-blooded animals is kept uniform through a balance being established between the heat formation and its dissipation through the lungs, skin, and other organs. If an excessive formation occurs, as during muscular exertion, this is counterbalanced by in increase in the output from the skin through the dilatation of the vessels and by the perspiration. If, on the other hand, more heat is dissipated than usual through exposure to cold, the combustion of the tissues is increased and more heat is formed. The output of heat is thus determined by the degree of dilatation of the cutaneous vessels and the activity of the sweat glands, while the amount of heat formed varies with the voluntary and involuntary contractions of the muscles. In order to preserve a balance between these two factors, there must exist a coördinating mechanism, and this is located in the basal ganglia of the cerebrum, in the neighborhood of the tuber cinereum. Lesions in this neighborhood generally cause a rise in the temperature, often without further disturbance, and it is of interest to learn that as long as the cerebrum is intact, shivering is produced by cold, while after section between the optic thalamus and the corpora quadrigemina the animal offers no resistance to a fall of temperature.

Other facts might also be adduced to show that in the normal animal the temperature is kept uniform by this coördinating mechanism, which controls both the output of heat through the skin and its formation by the contractions of the skeletal muscles. In many individuals this coördination is not perfect in health, and in all it may be disorganized by poisons, such as those formed in fever. The more perfect the coördination, the smaller is the divergence from the normal temperature necessary to elicit a protective increase in the combustion or in the dissipation. The efficiency of the mechanism may therefore be measured by observing what fall of the body temperature occurs before shivering sets in, what rise produces dilatation of the cutaneous vessels and perspiration. In this way it has been found that during fever the coördination is quite as perfect as in health, but that the protective reactions are induced at a higher temperature. The same measures are taken to preserve a uniform temperature

[1] Even when the nitrogenous metabolism is reduced by antipyretics in fever, it is said to be remarkably increased as the temperature rises again, so that no real economy of protein results from their use.

as in health, but the temperature maintained by these means is higher. If a comparison be made with the thermostat of the laboratory, it may be said that in fever the mechanism is "set" for a higher temperature than in normal life, but that the apparatus acts efficiently for each temperature. This higher temperature is maintained by an increased metabolism or heat formation, and also in most cases by a lessened dissipation. The fever temperature itself seems to increase the metabolism, the tissues undergoing more rapid waste under it than in normal conditions.[1] The coördinating mechanism appears to be more susceptible in fever to various influences, and the consequent variations in its activity cause the large undulations of the temperature curve which are characteristic of pyrexia. Among these influences is the temperature itself, for Barbour has shown that the overheated blood tends to change the activity of the centre so that the heat loss is augmented.

The antipyretics do not lower the temperature by reducing the heat production, for, though the nitrogen eliminated and the oxygen absorbed fall during their action in fever, this lessened tissue waste is the result not the cause of the fall of temperature, the metabolism proceeding more slowly when the heat is reduced.

Calorimetric investigations have shown that the dissipation of heat in fever is much increased by the antipyretics, while in health they seem to have little effect. This augmentation in the output is due to dilatation of the cutaneous vessels, which exposes a large amount of blood to the cold air. The dilatation is great enough to be recorded by the plethysmograph in many cases, while in others flushing of the skin may be observed. The increased dissipation of heat is accompanied by a lessened formation which, however, is much less important and which is generally attributed to the metabolism proceeding less actively at the lower temperature. In other words, the antipyretics reduce the temperature by increasing the output of heat, and the cells of the body grow and change less when removed from the hot-house temperature to which they have been exposed previously. It must be added, however, that some observers hold that the fall in heat formation is too great to be explained in this way, and suppose that the antipyretics lessen the combustion through some other action, but not by affecting the tissues directly. And Barbour states that the heat formed may actually increase under antipyretic treatment; this is usually masked by the increased heat loss, but in cases of abnormally low temperature, when the heat loss is not increased by antipyretics, it may actually lead to a rise of temperature under the drug.

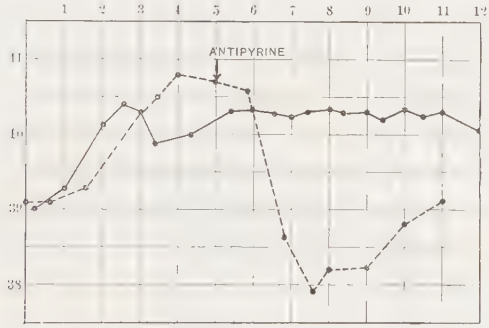
It has been stated already that the fevered animal resists any change in its temperature in the same way as the normal, and it might therefore be expected that when the temperature is reduced by antipyretics the organism would at once increase its heat formation. The fact

[1] It must not be supposed from the foregoing statements that fever consists only in an alteration of the normal temperature. This is only one of the symptoms produced by the poisons of fever, but is the only one affected by the antipyretics.

that this does not occur, but that, on the contrary, the metabolism is lessened, indicates that some further change occurs, that the antipyretics not only reduce the temperature by allowing the heat to escape, but also alter the condition of the coördinating mechanism by which the temperature is kept uniform. To return to the comparison with a thermostat, the body temperature is set at a lower point by the antipyretics, while it is set higher by the fever poisons.

The action of the antipyretics on this coördinating centre is therefore of interest, and has been examined both in health and disease. In healthy men the temperature does not undergo any marked change under the antipyretics, for though it may fall a few tenths of a degree in some cases, this is of no significance. The sensitiveness of the coördinating centre is increased apparently, however, for in some individuals in whom hard muscular work causes a rise of temperature normally, this is absent or less marked after the antipyretics. In the

FIG 66

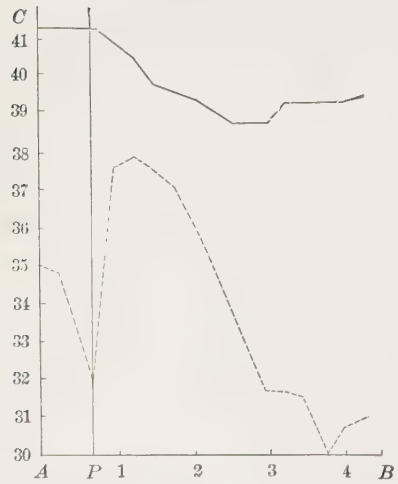


Temperature charts of two rabbits under fever toxins. The unbroken line was obtained from an untreated animal, the dotted line from one which received antipyrine at the point indicated by an arrow. The time is given in hours along the horizontal line; the temperature in degrees Centigrade on the vertical. (After Kiliani.)

same way the rise of temperature which occasionally is caused by very hot baths, is absent or diminished, when antipyrine has been administered previously. When the basal ganglia are cut off from their connections with the lower part of the body, neither septic infections nor antipyretics have any effect on the temperature, while after section above the basal ganglia, fever is caused, and the antipyretics induce the usual fall of temperature (Sawadowsky). In experiments in which high fever was produced by lesions in the neighborhood of the ganglia, Gottlieb found that the antipyretics reduced the temperature and increased the output of heat to a marked extent, while the formation was increased to a less degree. Further evidence that the antipyretics act on the regulating mechanism in the brain is afforded by experiments in which they were injected directly into the neighborhood of the centres, when much smaller quantities sufficed to reduce fever temperature than were necessary when they were carried to them by the blood.

Finally, the condition of the centre has been examined by Stern and Richter after the temperature had been reduced by antipyretics. They both found that the protective mechanism was called into play when the temperature was slightly raised, and generally when it was depressed. For example, a fevered dog (temperature 40.9° C.) received an antipyretic, and its temperature was reduced to 37.6°. Attempts were now made to raise the temperature by external heat, but the animal resisted this by increasing the output as soon as the temperature rose to 37.8°. The coördination which maintained the temperature at 40.9° before the drug was administered, now attempted to keep it at 37.6°.

FIG. 67



Curve of internal temperature (unbroken line) and of the skin temperature (dotted line) in fever treated with antipyrine (Rosenthal). The abscissa *AB*, represents the time in hours; the vertical, *AC*, the temperature Centigrade. At *P*, antipyrine was given, and the skin temperature rose at once (augmented heat output). The internal temperature soon began to fall, and after it had reached a certain point the skin temperature fell again as the vessels contracted.

The results of these researches may be summed up shortly as follows: The antipyretics reduce the temperature in fever through alterations effected in the heat-regulating nervous mechanism, which result in lowering the point at which the temperature is maintained. As a consequence of this action, a great increase in the dissipation of heat must occur in order to free the body from the warmth which it has accumulated, and this increased output is attained by dilatation of the cutaneous vessels. The seat of action of the antipyretics is probably situated in the base of the cerebrum.

Both antipyretics and fever toxins act upon the temperature-regulating mechanism, the one exciting, the other depressing it; the antipyretics may thus be regarded as acting as antagonists to these toxins in the brain in the same way as atropine antagonizes pilocarpine in the heart. The centre poisoned by the toxins is apparently more readily acted on than in the normal condition. The toxins are often regarded as stimulating, the antipyretics as depressing the centre, but there are equally valid grounds for reversing the roles and holding that the toxins depress and the antipyretics excite it (Barbour).

When the temperature is depressed too rapidly by these remedies, a condition of collapse is often produced, while in other cases the loss of heat caused by the dilatation of the skin vessels seems to be excessive, and shivering and rigor follow in order to increase the production.

When the temperature has reached the new point fixed by the coördination under the influence of the antipyretics, the heat dissipation rapidly diminishes and may become less than normal, because the new temperature is maintained at a constant point by the same mechanism as the normal.

The antipyretics are rapidly absorbed, and as rapidly **Excreted** by the kidneys, so that they disappear from the body within twenty-four to thirty hours after their administration.

The fate of antipyrine seems to differ in different animals. In the dog it is found to be partially oxidized to oxyantipyrine which is excreted in the urine in combination with glycuronic and sulphuric acids. In others it is said to be excreted in the urine unchanged. Acetanilide undergoes a partial oxidation, the final product differing in different animals, but none of the original body appears in the urine except after very large doses. In man it appears as paramidophenol and its compounds in combination with sulphuric and glycuronic acids. In the rabbit's urine paramidophenol alone is found, while in the dog this is accompanied by oxycarbanil ($C_6H_4O.NH.CO$); in each case it forms a double sulphate or glycuronate. The fate of the other antipyretics resembles that of acetanilide, the quinoline derivatives undergoing a partial oxidation resulting in a body analogous to paramidophenol, while the phenetidine compounds are partially decomposed and appear in the urine as glycuronates of phenetidine. The combinations containing salicylic acid break up in the body, and the acid appears in the urine, while the rest of the molecule undergoes the usual partial oxidation.

The presence in the urine of these bodies, or rather of further products of their oxidation, gives it a dark, reddish-brown color, which may be observed when it is passed, or more frequently after it has been exposed to the air for some time.

Preparations.

Antipyrina (U. S. P.), Phenazonum (B. P.) phenazone, or antipyrine, forms colorless inodorous crystals, with a bitter taste, very soluble in water, alcohol, and chloroform. 0.3 G. (5 grs.); B. P., 0.3–1 G. (5–15 grs.).

Phenacetinum (B. P.), Acetphenetidinum (U. S. P.), colorless, tasteless crystals, insoluble in water, 0.3 G. (5 grs.); B. P., 0.3–1 G. (5–15 grs.); given in powders, cachets, tablets, or suspended in mucilage.

Acetanilidum (U. S. P., B. P.), acetanilide or antifebrine, colorless crystals insoluble in water, soluble in alcohol, ether, and chloroform. It has no odor when pure, but has a slight burning taste. Dose, 0.2 G. (3 grs.).

Pyramidon (non-official) small colorless crystals slightly alkaline in reaction, almost tasteless, soluble in 11 parts of water. Dose, 0.3–0.4 G. (5–6 grs.) in tablets or powder.

The antipyretics are almost invariably given by the mouth. Antipyrine has been injected hypodermically, but this is somewhat painful, because much larger quantities have to be used than are generally given by this method, and the solutions have, therefore, to be more concentrated (30–50 per cent.).

Among the members of this group, phenacetine is probably that most widely used at the present time; antipyrine is also popular. Acetanilide is much more dangerous than these and should be discarded.

Therapeutic Uses.—The antipyretics were introduced to **Reduce the Fever Temperature.** The most satisfactory results are obtained from

those which act somewhat slowly, but which preserve a low temperature for some time, and antipyrine and the phenetidine compounds are thus preferable to the earlier remedies, which produce a more abrupt fall, after which the temperature soon regains its former height. The best effects are obtained when the antipyretic is given at the commencement of a natural remission, the temperature often falling 2–4 degrees in the course of the next two to three hours, and only rising slowly afterward. In some fevers the antipyretics have much less tendency to lower the temperature than in others. Thus in septicæmia larger doses are required than in typhoid and not infrequently no satisfactory reduction of the temperature follows the administration of the maximal quantity. Pneumonia is also said by some writers not to be affected so easily as some other febrile conditions in which the heat-regulating centre appears to be in a less stable condition, as is manifested by the occurrence of large spontaneous variations of temperature. The reduction of the temperature by the antipyretics lasts only as long as the drug is present in sufficient quantity in the body, and accordingly as soon as sufficient has been excreted, the intoxication of the regulating mechanism begins again, and the temperature soon rises to its former height. The antipyretics do not act on the cause of the disease, but only remove one of the symptoms, but this in itself is not an argument against their use, as is apparently believed by some writers, because as long as the physician is unable to treat the cause directly, he is justified in taking such measures as are possible to remove the symptoms, rather than in adopting an expectant treatment, pure and simple. The extensive use of these remedies shows very clearly that the high temperature is merely a symptom of disease, and not the disease itself, and the question has been much debated whether the reduction of fever is in any way beneficial. No one questions that some antipyretic measures should be taken when the temperature rises so high as to form a danger in itself, but their use in ordinary fever cases is more doubtful, and many physicians deprecate it unless in exceptional conditions. The very large doses formerly used undoubtedly induced dangerous symptoms occasionally, but there is little risk of this occurring from the intelligent use of the less violent members of the series. It has recently been shown by Schutze and Beniasch that the use of the antipyretics does not retard the formation of the protective substances (antitoxins) to which the recovery from fever is attributed, for in infected animals treated with enormous quantities of antipyrine the serum displayed the same agglutinating properties toward the bacilli as that of controls which were not subjected to any medication.

A more serious argument against their use in fever is that the course of the disease is less readily followed, because one of the guiding symptoms—the temperature variations—is no longer dependent solely upon the severity of the intoxication with the fever poisons, and both diagnosis and prognosis are thus rendered more difficult. For example, in typhoid fever a sudden fall of temperature often

gives the first indication of such a complication as hæmorrhage, but if an antipyretic has been given beforehand, this indication may be entirely absent. On the other hand, it is urged in favor of the antipyretic treatment that the patient feels more comfortable and easier when the temperature is reduced, and that this alone may favorably influence the course of the disease. Besides, the high temperature in itself increases the tissue waste and causes larger draughts on the resources of the patient than would be made with the same amount of poison in the tissues at a lower temperature; and although the influence of the high temperature on the metabolism was undoubtedly exaggerated at one time, this consideration is by no means devoid of weight. The theory that fever is a defensive measure taken by the organism against the causes of disease and ought not to be interfered with therefore, is now seldom mentioned, but has cropped up in a new form; it is said that the constriction of the skin vessels serves the purpose of directing the blood toward the vital internal organs, and that the antipyretics in dilating the skin vessels counteract this useful measure; cold bathing, at any rate at first, rather tends to divert further the blood from the skin, while at the same time withdrawing heat from the body.

The antipyretic treatment of fever is of value, then, in cases where the temperature is so high as to endanger life, in cases in which the rise of temperature is the chief cause of distress and no complications are to be apprehended, and, in general, in cases in which the increased comfort of the patient is not counterbalanced by its obscuring the diagnosis and prognosis. On the other hand, there is no reason to suppose that it lessens the mortality or shortens the course of most fevers, or that it prevents complications of any kind except excessively high temperature, and the routine treatment of fever with antipyretics is to be deprecated.

The chief rival of the antipyretics in the treatment of fever in the present day is the so-called cold-bath treatment, in which the fever patient is bathed frequently in water the temperature of which varies from 70–90° F. in different hospitals. The temperature generally falls to a considerable extent under this treatment, and very often a general improvement in the symptoms occurs. The effect on the temperature is mainly due to the abstraction of heat from the body, and thus far corresponds to that of the antipyretics. In the cold-bath treatment, however, the loss of heat is not immediately due to the dilatation of the skin vessels, for baths at 70° F. have rather the effect of constricting the vessels primarily, whatever may be the subsequent effect. The heat output increases here from the change in the external medium, and not from any alteration in the skin itself. The fall of temperature is generally not so great as under the antipyretics, and the regulation is not directly affected, for the patient shivers and becomes cyanotic long before the normal temperature is reached. The therapeutic virtue of the cold bath was formerly believed to lie exclusively in the abstraction of heat and the fall of

temperature, but many advocates of the treatment now hold that this is of less importance than the effects on the circulation and the brain, which are elicited reflexly by the cold water applied to the skin, and which are not now believed to be due to the fall in temperature. Whether this view is correct or not, the whole nature of the fall in temperature is different from that produced by the antipyretics, and the metabolism, instead of becoming less active as it does under the latter, rather tends to increase under the cold baths, at least as far as the tissue change can be measured by the nitrogen excreted. The relative therapeutic value of the two methods of treating fevers can only be determined by clinical experience, and the clinicians do not appear to be so enthusiastic in their advocacy of the cold bath as they were a few years ago. However the matter may stand in hospital practice, in which trained assistance is available, the antipyretics have a great advantage in many cases in which treatment has to be carried out without any such facilities, for the administration of these drugs may, of course, be entrusted to ordinary persons, whereas the cold bath can be given only by the physician himself or by trained attendants. Particularly in the milder fevers, where no complicated measures, such as the cold bath, are considered necessary, the antipyretics give relief to the patient by removing the feeling of heat and discomfort.

Other antipyretic drugs are quinine and alcohol, but neither of these produces an equal fall of temperature unless with the presence of alarming and dangerous symptoms. These drugs are used less as antipyretics now than formerly, as, besides their undesirable secondary effects, the fall of temperature is less certain and less profound than under the modern antipyretics.

The antipyretics are also used very largely to relieve **Pain and Discomfort**, often with complete success. The analgesic action of these bodies is apparently quite different from that of morphine, for in many instances in which the latter is successful they fail to alleviate the condition. On the other hand antipyrine and its allies can often be used where morphine is contra-indicated, either from the danger of the habit being formed, or from the somnolence it induces. They were first used in neuralgic pain and headache, but have been found equally efficient in other forms of pain and discomfort, and the relief given in fever appears to arise from this analgesic action as much as from the reduction of the temperature. It is not possible at present to specify the characters of the pains which they relieve or to distinguish them from those in which recourse must be had to morphine; in very severe pain and especially in those forms in which it arises from spasmodic contraction of hollow organs, the antipyretics are of little service, while pain arising from affections of the nerves is more amenable to their action. Phenacetine and its allies are frequently used for this purpose, antipyrine less often at present; acetanilide should be avoided. Acetylsalicylic acid has been used instead of the antipyretic group of late years. Caffeine is often prescribed along with the antipyretic in headache and neuralgia.

Several of the antipyretics have been used as **Substitutes for Quinine**

in the treatment of malaria, but none of them have the specific action of the latter on the organism of malaria, and, although they may reduce the temperature, they do not prevent the other symptoms and do not remove the cause of the disease. In the same way they do not seem to equal salicylic acid in efficiency in acute rheumatism, although here again they reduce the temperature. Even those which release salicylate in the body, such as malakine and salophen, do not supply adequate amounts of it for the treatment of rheumatic fever, in which the pure salicylate is much to be preferred.

The antipyretics have been used in cases of diabetes insipidus and mellitus and appear to relieve the discomfort and in some cases to improve the general condition. In whooping-cough antipyrine often lessens the severity of the attacks and also renders them less frequent, and is said to shorten the course of the disease.

The use of antipyrine and other members of this series as sedatives in hyperactivity of the motor functions of the brain, such as epilepsy and chorea, has not been attended with great success, although temporary improvement has occasionally been noted, as after so many other remedies.

Antipyrine and several others of this series have been advocated as local sedatives or anæsthetics, and have been used occasionally to lessen the irritability of the throat and larynx and thus to permit of the minor manipulations of laryngology. Holocaine, a body closely related to phenacetine, has been employed to a limited extent as a local anæsthetic in ophthalmology.

The occurrence of collapse and other symptoms has led to a considerable amount of distrust of the antipyretics among many of the medical profession. In justice it has to be remembered that in many cases these symptoms were produced only by very large doses, and that since experience has shown that beneficial results may be obtained by smaller quantities, these cases have notably diminished in medical practice. Unfortunately, this distrust is not entertained by a large class of the laity, and numerous cases of poisoning arise from the impression that the antipyretics are not dangerous drugs. For the most part, poisoning seems to be due to a peculiar sensitiveness or idiosyncrasy, which cannot be foreseen, but in cases of great exhaustion and asthenia, especially when accompanied with anæmia, these drugs have to be used with great care or avoided entirely.

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Tetrahydronaphthylamine.

A poison may be mentioned here which has the property of causing fever temperature and even proves fatal from hyperthermia in some cases. Tetrahydro-β-naphthylamine ($C_{10}H_{11}NH_2$) raises the temperature by increasing the heat production through muscular movement and by limiting the heat loss through constriction of the vessels of the skin and superficial tissues. The muscular movement arises from central nervous excitation, and is shown in tremor and convulsions after large doses; the oxygen absorption and the carbonic acid production is greatly augmented. The constriction of the cutaneous vessels is also mainly due to stimulation of the vasomotor centre, though there may be some slight action on the vessel walls also. The pupil is widely dilated and the eyeball is protruded, from stimulation of the sympathetic mechanism, partly in the periphery but mainly in the central nervous system. Cocaine has a similar but weaker action; the naphthylamine compounds do not cause local anæsthesia.

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XXXII. SALICYLATES.

Salicylic Acid, $C_6H_4OHCOOH$, was introduced into medical use as a substitute for carbolic acid, but its chief interest now lies in the use of its sodium salt in acute rheumatic fever. Some of the esters have also been employed; *methyl salicylate*, $C_6H_4OHCOOCH_3$, which is found in the volatile oil obtained from the *wintergreen* (Gaultheria procumbens) and from *birch bark* (Betula lenta) and which is also formed synthetically; *phenyl-salicylate* or *salol*, $C_6H_4OHCOOC_6H_5$, formed synthetically; the numerous other salicylic esters which have been introduced by enterprising manufacturers have not attained a wide use. A recently introduced compound which has been largely employed is *acetyl-salicylic acid*, $C_6H_4OCOCH_3.COOH$, or *aspirin*. *Salicin*, $C_{13}H_{18}O_7$, is a glucoside found in the poplars and willows, which forms salicylate in the body and has had a limited use.

Local Action.—Salicylic acid has some value as an antiseptic, largely from its acidity, and the neutral salts are almost devoid of this property; thus protein solutions do not putrefy and the alcoholic and acetic acid fermentations are retarded by comparatively small quantities of salicylic acid while the salicylates are almost inert. The salicylic preparations are generally less efficient than phenol in the presence of proteins, probably because the latter is more volatile and forms less stable combinations and therefore penetrates more readily. Salicylic acid, on the other hand, does not evaporate and therefore preserves objects which are exposed to the air for a longer time than carbolic acid, which is soon dissipated. The movements of plant protoplasm, protozoa and leucocytes are prevented by salicylic acid, which also retards the digestion of proteins by the gastric and pancreatic juices, and the decomposition of glucosides by ferments, but this is probably due to its acidity and not to the salicylate ion.

Irritant Action.—When salicylic acid is applied for some time as a powder to wounds, mucous membranes, or even the skin, it may induce corrosion and necrosis. It sometimes causes soreness and irritation of the mouth and throat when swallowed in powder, and congestion and even erosion of the mucous membrane of the stomach have been observed; even dilute solutions often cause pain and discomfort in the stomach. Sodium salicylate is only very slightly irritant, but when it is swallowed, some of the acid is disengaged by the hydrochloric acid of the stomach and may be deposited on the mucous membrane and give rise to acute dyspepsia.

Symptoms.—Salicylic acid and its salts are rapidly absorbed from the intestine and as a general rule produce no symptoms, unless when given in large doses. Some individuals, however, are peculiarly sensitive to the action of the salicylates, and in these comparatively small doses are followed by symptoms which are generally of only slight importance, but which are sometimes sufficiently grave to cause anxiety, and in very rare cases have been followed by death.

The ordinary symptoms are a feeling of heaviness and fulness in the head, with hissing or roaring sounds in the ears exactly resembling those produced by quinine. These may be followed by some confusion and dulness and by indistinct sight and hearing. Very often the patient complains of excessive perspiration and a sense of warmth all over the body. Dyspnœa, marked by exceedingly deep and labored respiration, has been noted in more serious cases of poisoning, and a condition of collapse with slow, weak pulse, subnormal temperature and partial or complete unconsciousness may follow. In others delirium and hallucinations of sight and hearing have occurred, these being more frequently seen in chronic alcoholic patients and in cases of diabetes than under other conditions. Albumin, casts and even hæmoglobin and blood in the urine are often noted as sequelæ. Various forms of skin eruptions have been described as occurring under the use of salicylic acid, sometimes after a single dose, but more frequently after prolonged treatment. They resemble those seen

under the antipyretics, but seem to be less frequently elicited by salicylic acid. Hæmorrhages from the nose, mouth, intestine and uterus have also been credited to the action of this drug, and the last may explain the occasional occurrence of miscarriages under it; it has no influence on the uterine movements in the concentrations found in the blood in man, though stronger solutions increase the contractions in animals. Numerous other symptoms have been noted after it, but so rarely that a doubt may be entertained as to whether they were not due to some special condition, or perhaps to some impurity in the drug.

In animals salicylates injected intravenously cause some acceleration of the pulse and respiration, followed by slowness and weakness of the heart, and often by marked dyspnœa. Depression of the central nervous system is shown by slowness, weakness and incoördination of the spontaneous movements, and eventually by stupor and arrest of the respiration, which is generally preceded by convulsions. Photophobia and clonic spasms have been observed in some dogs. Hyperæmia of the kidney, liver, brain and tympanum are sometimes found at the autopsy on dogs poisoned with salicylates, and when the drug has been given in powder, congestion, irritation, and necrosis of the gastric mucous membrane. This irritation of the stomach often causes vomiting in dogs, and the poison being thus eliminated, no further symptoms appear. Vomiting occurs in cats when salicylate is injected hypodermically, which indicates some action on the medullary centres; increased reflexes, tremors and restlessness are also described in these animals in which a more distinct stimulation of the central nervous system seems to be elicited than in man.

In the frog salicylic acid produces quickened respiration and increased reflexes, followed by depression of the spontaneous movements, tremor, and clonic contractions. The heart is slow, dilated, and weak.

The symptoms elicited by salicylic acid and its salts are therefore very indefinite, and with few exceptions occur so seldom in man that they may be discussed shortly.

The **Disorders of Hearing** have been ascribed to congestion of the tympanum, but may perhaps indicate some changes in the nerve cells of the ear analogous to those observed under quinine. As a general rule they pass off in the course of a few hours or days, but they sometimes leave a more or less permanent impairment of the sense of hearing. The **Dimness of Sight**, sometimes amounting to complete blindness, is due to vascular or retinal changes in the eye (see Quinine), and some disturbance of the circulation of the brain and head may be the cause of the dulness and fulness of the head complained of, and of the not infrequent epistaxis. Maragliano showed by plethysmographic measurements that the **Vessels of the Skin** are dilated by salicylates in the same way as by the antipyretics.

The general **Blood-Pressure** is found to be increased by small quantities of the salicylates from stimulation of the vaso-constrictor centre, while after very large injections into the bloodvessels, the pressure is lowered, partly perhaps from depression of the centre, but mainly from the cardiac action of the drug.

Small quantities may accelerate the **Heart** in animals in the same way as small doses of the other aromatic bodies, apparently from direct action on the cardiac muscle. Very large doses produce a slow, weak and dilated heart, and a corresponding fall in the blood-pressure. Friderichsen found that 0.12 per cent. of salicylate in the blood causes no symptoms from the heart, but any higher content is injurious.

The acceleration of the **Respiration** and the dyspnœa which have been noted occasionally in man, seem to be due to some central action. In animals the respiration is first accelerated to some extent, and then slowed, apparently from the respiratory centre being first excited and then depressed, and eventually paralyzed by very large quantities of the drug. Death seems to be due to this paralysis, the heart continuing to beat for some time afterwards.

The effects of salicylates on the **Central Nervous System** seem to be comparatively slight, except in cases in which a special idiosyncrasy exists. No such convulsive action as occurs under others of the aromatic series has been observed under it, and in animals there seems no marked depression save in the medulla oblongata. The convulsions which are observed before death are probably not due to the direct action of the drug, but to the asphyxia. In the medulla oblongata the respiratory and vaso-constrictor centres, and probably the vaso-dilator, seem to be first stimulated and then depressed.

The **Perspiration** which so often follows the administration of salicylic preparations may be due in part to the dilatation of the skin vessels, but is probably to be ascribed rather to increased activity of the sweat centres. Some of the **Skin Rashes** may also be caused by the dilatation of the cutaneous vessels, and perhaps in all cases this may be looked upon as a favorable condition, which leads to eruptions in individuals who are predisposed to them.

Salicylic acid and its salts increase to some extent the **Secretion of the Urine**, probably through a direct action on the renal epithelium, although the increased formation of urea may also play a part in the slight diuresis. Irritation of the kidney and nephritis are observed in many cases, with the appearance of albumin and blood in the urine.

The salicylic preparations produce a slightly augmented flow of **Bile**, apparently from some specific action on the liver cells. The bile is generally more dilute than normal, the fluid increasing more than the solids, though the total solid excreted is augmented.

Salicylate has been said to lower the normal **Temperature**, but this seems to be erroneous, except when very large quantities produce a condition akin to collapse. In fever patients, however, it often causes a marked fall of temperature, and it was formerly used as an antipyretic for this reason. The action is probably explained by the dilatation of the cutaneous vessels and the increase in the output of heat. (See Antipyretics.) Dilatation of the skin vessels also occurs in normal persons after salicylates, but this is counterbalanced in them by increased heat formation. The fall in temperature after salicylic acid is generally less in extent and of shorter duration than that following the members of the antipyrine series.

In its passage through the tissues, salicylic acid modifies the **Metabolism**, as is shown by an increase of 10–12 per cent. in the nitrogen and sulphur of the urine. This indicates a considerably augmented decomposition of the proteins of the body, but whether it is accompanied by increased oxidation is unknown. A still more notable augmentation of the uric acid excreted has been observed, different authors estimating it at 30–45 and even 100 per cent. This occurs also in animals and persons on a purine-free diet; the uric acid escapes through the kidney more easily, and the percentage in the blood falls as that of the urine rises. (See Atophan, p. 452.)

Salicylate circulates in the blood as the sodium salt; most of it is carried in the plasma, but some passes into the corpuscles; it does not accumulate in the joints more than elsewhere, as was asserted. About three-fourths of that ingested is **Excreted** by the kidneys, for the most part unchanged, in smaller amount in a combination with glycine, which is known as salicyluric acid, and which is strictly analogous to hippuric acid; salicyluric acid seems practically inert, and has no effect in acute rheumatism. It appears in the urine within an hour of its administration by the mouth and is all eliminated in forty-eight hours. It has also been found in the milk, perspiration and bile, but does not appear to be excreted into the stomach. About 20 per cent. or more is completely destroyed in the tissues and this fraction is higher in rheumatic fever than in normal persons; the actual concentration in the blood and urine may thus be lower in rheumatic fever.

Methyl Salicylate has a hot, burning taste, and like other volatile oils produces a feeling of warmth in the stomach, In many cases it is well borne, but some patients complain of pain in the stomach, loss of appetite, and even nausea and vomiting. Much of it is decomposed to salicylate in the intestine and this is rapidly absorbed and produces the characteristic symptoms in large doses. Much less salicylate is excreted in the urine than after the corresponding sodium salt, and some of the oil reappears unchanged.

Salicin, a glucoside found in many species of willow and poplar, is decomposed into salicylic alcohol, which is oxidized to salicylates in the body. It is probable that the decomposition, like that of the ordinary esters, takes place chiefly in the intestine, for when it is injected intravenously it is excreted unchanged. It is very bitter, but does not irritate the mucous membranes, and is not so certain in its action as salicylate. When administered by the mouth it is excreted in the urine partly as salicin, partly as saligenin or salicyl alcohol, and partly as salicylic and salicyluric acids.

Acetylsalicylic Acid, or **Aspirin**, passes through the stomach unchanged and is free from the gastric effects of salicylic acid and the salicylates. It is partially decomposed into salicylic acid in the bowel, but some of it is absorbed in its original form. The salicylate formed from it exercises its usual action in the tissues, but there is a further action resembling that of the antipyretics in headache and neuralgia, and this is attributed to the action of the acetylsalicylate which has escaped decomposition and has been absorbed.

Salicylic acid is ortho-oxybenzoic acid, and there are two isomers, *metaoxybenzoic* and *paraoxybenzoic* acid, which differ from it structurally only in the relative position of the hydroxyl and carboxyl side chains. Yet their salts are devoid of action in acute rheumatism and are not employed in therapeutics.[1]

The three isomeric *cresotinic acids* ($C_6H_3.CH_3.OH.COOH$) that correspond to salicylic acid in the position of their hydroxyl and carboxyl groups, resemble it in action and are effective in acute rheumatism; they are approximately equal to salicylic acid in toxicity, but orthocresotinic acid has a more depressant action on the heart, and as they offer no advantages over salicylates, they have only been used experimentally in therapeutics.

Preparations.

Sodii Salicylas (U. S. P., B. P.), sodium salicylate ($C_6H_4OHCOONa$), a white, odorless powder with a sweetish taste, very soluble in water, less so in alcohol.[2] 1 G. (15 grs.); B. P., 10–30 grs. in capsules or tablets, or dissolved in syrup.

Acidum Salicylicum (U. S. P., B. P.), salicylic acid ($C_6H_4OHCOOH$), small, white, needle-like crystals, or a light crystalline powder, odorless with a sweetish, afterward acrid, burning taste, slightly soluble in water, very soluble in alcohol or ether. A reddish tinge indicates the presence of carbolic acid or other impurities.

Unguentum Acidi Salicylici (B. P.), 2 per cent.

Oleum Gaultheriæ (B. P.), oil of wintergreen, a colorless or yellowish fluid with a characteristic, pleasant odor and a sweetish, aromatic taste, insoluble in water, soluble in alcohol, contains 90 per cent. of methyl salicylate, 5–15 mins.

Methylis Salicylas (U. S. P., B. P.), ($C_6H_4OHCOOCH_3$), is practically identical with the oil of wintergreen. Dose 0.75 mil (12 mins.).

Salicinum (U. S. P., B. P.), salicin ($C_6H_{11}O_5OC_6H_4CH_2OH$), a glucoside obtained from several species of willow and poplar, consists of white, silky, crystalline needles, with a very bitter taste, soluble in 28 parts of water. 1 G. (15 grs.); B. P., 5–20 grs. or more every 3 or 4 hours, given in powder, capsules or in solution, which, however, is very bitter.

Acidum Acetylsalicylicum (B. P.), *Aspirin* ($C_2H_3O—OC_6H_4COOH$) is composed of small colorless crystals, without odor, and is slightly soluble in water with a more pleasant acid taste than salicylic acid. It has appeared under numerous designations of late years. Dose, 0.3–1 G. (5–15 grs.).

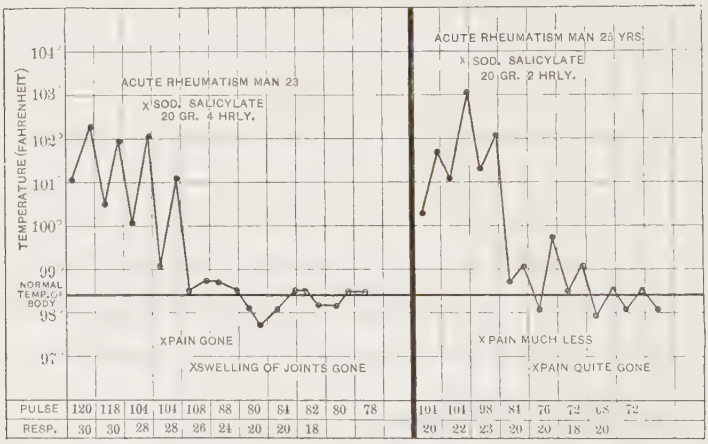
Therapeutic Uses.—The chief sphere of usefulness of salicylate at the present time is in the treatment of acute rheumatic fever, in which it seems to have a specific action similar to that of colchicum in gout. Some other members of the aromatic series are useful in this condition, but none are superior to the salicylic preparations in efficacy. Under this treatment the pain and swelling in the joints rapidly lessen, the temperature often falls, and the disease makes less demands on the strength and courage of the patient; it is a question whether it acts on the unknown cause of the disease, and Hanzlik holds that it is a purely symptomatic treatment and that salicylate may be substituted

[1] This difference in activity between the stereoisomers of the benzene series is very frequently met, and the relative toxicity differs in the different compounds; thus the ortho-compound is most active in the oxybenzoic acids (salicylic acid), while among the cresols the metacresol is said to be the most poisonous, and parachlorphenol is more antiseptic than either of its isomers.

[2] Salicylate formed synthetically from phenol is often said to be more poisonous than that obtained from the oil of wintergreen (methyl salicylate), but this is not correct.

by a mixture of other antipyretic and analgesic remedies. It is still debated whether the salicylic treatment reduces the liability to endocarditis and pericarditis, which are common complications of acute rheumatic fever; some clinicians even state that it increases the risk of these complications, while others advise the discontinuance of the treatment when any symptoms arise from the heart. The view more generally entertained, however, is that the cardiac affections are less often met with and are less severe under salicylic treatment, and very often it is continued in small quantities even after the heart is undoubtedly involved in the disease. The remedy sometimes fails in rheumatism, as quinine does in malaria, and it sometimes acts more satisfactorily in one joint than in another. Relapses occur even during the continuous treatment with ordinarily adequate quantities of salicylate, and it is found

FIG. 68


TEMPERATURE (FAHRENHEIT)
104
103
102
101
100
99
NORMAL TEMP. OF BODY
98
97
ACUTE RHEUMATISM MAN 23
X SOD. SALICYLATE 20 GR. 4 HRLY.
X PAIN GONE
X SWELLING OF JOINTS GONE
ACUTE RHEUMATISM MAN 23 YRS.
X SOD. SALICYLATE 20 GR. 2 HRLY.
X PAIN MUCH LESS
X PAIN QUITE GONE
PULSE 120 118 104 104 108 88 80 84 82 80 78
RESP. 30 30 28 28 26 24 20 20 18
PULSE 101 104 98 84 76 72 68 72
RESP. 20 22 23 20 20 18 20

Clinical charts of cases of acute rheumatic fever treated with salicylate of sodium. Case 1, 20 grains every four hours; Case 2, 20 grains every two hours. (Stockman.)

advisable to keep the patient under observation as long as was necessary before the salicylate treatment was introduced. (Miller.) Large doses (1–2 G. or 15–30 grs.) repeated every two to three hours are necessary in some cases at first, the quantity being reduced as the symptoms abate. Salicylic acid is now seldom given, sodium salicylate having supplanted it. Alkaline carbonates are frequently recommended along with the salicylate, on the ground that they lessen the gastric action by preventing the formation of the irritant salicylic acid. Oil of wintergreen may also be used here, but, like salicylic acid, is more liable to cause gastric irritation. Salicin is less disturbing to the stomach than the other preparations, but is less certain in its effects and has to be given in larger quantities. Atophan or cinchophen (p. 452) has been found efficient as a substitute for salicylate in rheumatic fever but seems to have no definite advantage over it.

In other acute constitutional diseases accompanied by fever, salicylate has no such specific action as in acute rheumatic fever; even when the joints are involved, as in gonorrhœal arthritis, salicylate is of little or no service, so that some special relation appears to exist between the salicylate and the cause of rheumatic fever.

Salicylates have also been used in the various forms of disease which are roughly classified as rheumatic—chronic rheumatism, arthritis, neuralgia, myalgia—but the effects are less satisfactory than in acute rheumatism.

Salicylate in some cases promotes the absorption of effusions into the serous membranes, such as the pleura, and also subretinal effusion. It is unknown how this is effected, but it scarcely seems probable that the slight diuretic action of the drug is sufficient to account for it.

The cholagogue action of the salicylates is quite inconsiderable in comparison with that of the bile itself, and in any case in which an increase of the bile secretion is desirable, recourse should be had to the latter. It has recently been suggested by Kuhn that the salicylic salts excreted in the bile may retard the growth of microbes and thus prove of value in the treatment of liver and gall-bladder infections.

Salicylic acid is occasionally applied locally in excessive sweating, and has also been used in various skin affections in which it is desirable to soften or partially dissolve the epidermis; it is the chief constituent of many "corn-salves." Both acid and salts are absorbed too rapidly to act as intestinal disinfectants.[1] (See p. 132).

Salicylate is hardly used as an antipyretic at the present time, and has no value as a substitute for quinine in malaria, for which it was suggested.

Salicin is used as a substitute for salicylic acid only in rheumatic fever. It has been prescribed as a stomachic bitter.

Acetylsalicylic acid is used chiefly to relieve headache and neuralgia in the same way as the antipyretic group, and for this purpose may be given in doses of 0.3 G. (5 grs.) in tablets.

Salicylic preparations have to be used with care where any symptoms of renal irritation are present. In cases of poisoning, the treatment is determined entirely by the symptoms, and no antidote is known. Glycine has beeen suggested for the same reason as the sulphates in phenol poisoning, but would presumably be of no greater value.

Methyl salicylate, or oil of wintergreen, is often applied locally in muscular and articular rheumatism, it being supposed that larger quantities thus reach the focus of disease than when the drug is taken by the mouth. Absorption certainly occurs through the skin, as is proved by the appearance of salicyluric acid in the urine. But irrita-

[1] Salicylic acid has been used very largely as a preservative in wine and beer. No evil effects have been definitely shown to follow the prolonged use of liquors thus treated, but they may tend to disturb the digestion, and several governments have found it advisable to prohibit its use for this purpose.

tion of the skin is liable to be excited, and the value of the salicylates is doubtful in these diseases. Several other artificial compounds have been suggested in place of wintergreen oil in external treatment, but have no advantages over the older drug.

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Benzoic Acid and Benzoates.

Benzoic acid and its salts resemble the salicylic preparations closely in their action in most points, the acid being antiseptic and irritant, while the salts are less active in this respect. Benzoates have less action on the central nervous system and the disorders of hearing which are characteristic of the salicylates, have not been observed. Nausea and vomiting occur from very large quantities in man and it is believed that the expectoration is increased by the use of small doses of benzoates in bronchial catarrh.

Benzoic acid (C_6H_5COOH) combines with glycine in the kidney and in other organs to form hippuric acid ($C_6H_5CO-NHCH_2COOH$), which is excreted in the urine; some of the benzoic acid escapes in the urine unchanged, the proportion of hippuric acid formed apparently varying with the dose administered and other conditions; and some appears to be excreted in combination with glycuronic acid when very large doses are administered. The amount which is formed to hippuric acid does not increase significantly when glycine is administered along with benzoic acid, yet the glycine seems to lessen the tendency to convulsions in animals. In birds benzoic acid is excreted by the kidneys as ornithuric acid ($C_{19}H_{20}N_2O_4$), from which benzoic acid can be split off, leaving ornithin. Benzoic acid often increases the nitrogen eliminated in the urine, so that in these cases it augments the decomposition of the proteins like salicylic acid; in other investigations no material change has been observed, probably because the benzoic acid was changed too rapidly to hippuric acid to admit of its action on the metabolism being developed. It differs from salicylic acid in reducing the uric acid excretion. Some diuresis occurs after benzoic acid, and the acidity of the urine increases in the same way as after other acids which do not undergo combustion in the tissues.

Cinnamic acid ($C_6H_5—CH=CH—COOH$) seems to resemble benzoic acid in its pharmacological characters, but has not been so carefully examined. It increases the leucocytes of the blood and the uric acid of the urine to a marked degree.

Acidum Benzoicum (U. S. P., B. P.) (C_6H_5COOH), benzoic acid or flowers of benzoin, forms white crystals, almost odorless, with a warm acid taste, very insoluble in water, soluble in alcohol, ether, fixed and volatile oils and in alkaline solutions. 0.5 G. (8 grs.).

Sodii Benzoas (U. S. P., B. P.), easily soluble in water. 1.0 G. (15 grs.).

Ammonii Benzoas (U. S. P., B. P.), 1.0 G. (15 grs.)

Benzoic acid has sometimes been employed as an antiseptic, and sodium benzoate has been credited with some virtues as an intestinal and genito-urinary disinfectant. The treatment of gout and other diseases with benzoates on the theory that they lessened the uric acid excretion is obsolete. Ammonium benzoate has been given to increase the acidity of the urine, but is not so useful as the acid sodium phosphate. Benzoic acid is still an ingredient in many expectorant mixtures, generally in the form of benzoin or balsam of Tolu.

XXXIII. TOXINS AND ANTITOXINS.

The toxins are a series of poisons whose existence has been recognized only in recent years and whose character is still obscure, but they play an ever increasing part in medicine. They are found in animals and in some of the higher plants, and have proved to be the means by which many of the pathogenic micro-organisms act in the tissues. Their chemical characters are still disputed, and none of them have been isolated in an absolutely pure form, as no means has yet been found to separate them from the proteins in which they are intermixed. They are generally regarded as proteins, but they may be of simpler composition and merely attached by physical or loose chemical bonds to the proteins which accompany them.

These toxins are amongst the most powerful poisons known, but when animals are treated with small and gradually increasing doses, they become insusceptible to amounts that would prove fatal to an untreated control animal, and finally withstand in some instances many hundred times the ordinarily fatal dose. This acquired **Immunity** at first sight resembles the tolerance developed for morphine and other poisons, but is different in character. For in tolerance the organism no longer reacts to the poison, which has become one of its usual constituents, exactly as a fresh water organism may slowly be rendered tolerant to sea water, the salts of which are gradually added to the fresh water and come to form part of the normal environment of the organism. On the other hand, when immunity to a toxin is acquired by repeated administration, the organism forms a new antagonistic substance known as *antitoxin*, which prevents the toxin from having any effect by forming a loose combination with it, which is innocuous. Ehrlich has attempted to explain the formation of antitoxin in his well-known side-chain hypothesis by supposing that toxins combine with certain components of the living cells and that the organism reacts by forming those components in excess and freeing them in the blood

serum. When toxin is injected into an immune animal, it attaches itself to these bodies in the blood and, its affinity being satisfied, it can no longer become linked to the cells as it would in an unprotected animal; the poisonous action is thus prevented because the toxin is unable to combine with the cells on which it ordinarily acts. The organism forms these antitoxins far in excess of what is necessary to neutralize the quantity of toxin administered. And this excess can be obtained by bleeding the immune animal and collecting the serum; and when injected into an untreated animal this antitoxic serum lends it a certain degree of immunity to the subsequent injection of the original toxin. The use of this antitoxic serum may thus protect animals from the toxin of a disease, provided it be administered early. After the toxin has reached the tissues, antitoxin is of less benefit owing to the damage already done, and perhaps because it has difficulty in entering the cells, and the later the antitoxin is employed the less beneficial action it has.

Each antitoxic serum antagonizes only the toxin which has been employed in its production, and affects only the toxin and not the organism which may have produced it. For example, the antitoxin for diphtheria toxin has no influence on tetanus toxin and is powerless against the diphtheria bacillus, which grows readily in the antidiphtheritic serum. On the other hand diphtheria toxin has no effect in an animal protected by an efficient dose of the diphtheria antitoxin. Each toxin must thus be combated by the corresponding antitoxin, and the infection is not antagonized, but only the poison produced by the organism.

The nature of antitoxins is unknown, as none of them has been separated from the serum proteins; they are colloids and are destroyed by heat and by ferments, though less unstable than the toxins; it is probable that the antitoxin molecule is considerably larger than the toxin. The character of the combination formed on mixing a toxin with its antitoxin is still uncertain, but appears to resemble that between a weak acid and a weak base, for it can be resolved into its two constituents by physical and chemical methods.

The immunity acquired by treating an animal with a toxin (active immunity) persists in greater or less degree for many months or years, but the passive immunity given by the injection of antitoxic serum is lost comparatively soon owing to the destruction and excretion in the urine of the antitoxin.

The antitoxins are destroyed by the digestive ferments and have no action when given by the alimentary canal; they act slowly when injected subcutaneously, more rapidly intramuscularly and immediately by intravenous injection.

The antitoxic sera are entirely devoid of action except as antidotes to the toxin, provided they are injected into animals of the same species as that from which they are obtained. In therapeutics, animal serum has to be employed in man, and occasionally this gives rise to symptoms such as erythema and urticaria or other skin eruptions, fever and rheumatic pains in the joints and muscles; these, though unpleasant and sometimes alarming, have no serious results, and are equally liable

to arise when animal serum devoid of any antitoxin action is injected into man. This "serum sickness" only occurs in certain individuals, who are especially susceptible to horse serum; it is apparently a mild form of anaphylactic shock (see p. 389) and does not arise from the antitoxin itself but from the other constituents of the serum. More rarely, the shock is well developed and may prove rapidly fatal from collapse or asphyxia from bronchial constriction. This anaphylaxis apparently arises from the tissues having been sensitized by having come into contact with the foreign protein, though it is often impossible to ascertain how this occurred. It is of the first importance in the use of these sera to find out if horse serum has been previously used for diphtheria or any other purpose, and in that case a small injection (0.2 c.c.) is made to desensitize the patient and when this has been done, the larger therapeutic dose is given. Anaphylaxis is only developed after ten to fifteen days, so that repeated injections may be made within that interval without danger.

Apart from their action on the toxins, serums may also be specifically bactericidal, destroying or retarding the growth of the bacillus while affecting the toxin to a less extent. But these may be better treated of in connection with the microbes on which they act and by which they are formed.

Antidiphtheritic Serum.

When a horse is treated with injections of gradually increasing doses of diphtheria toxin, it acquires immunity to this poison, and its serum is found to neutralize the effects of large amounts of toxin injected into other animals. Blood is then drawn from the immunized horse, the serum is allowed to separate and is collected in sealed tubes; some antiseptic such as carbolic acid or cresol is added to preserve it. The amount of antitoxin in any serum must be ascertained, and this is done by animal experiment, the antitoxin unit being the amount necessary to protect an animal against 100 times the fatal dose of toxin for a guinea-pig of 250 G. weight. The antidiphtheritic serum is thus sent out standardized in units, some preparations containing 100 units in the c.c. and others as many as 300 or even 500 units.

Serum Antidiphthericum (U. S. P.), Antidiphtheritic Serum, or Diphtheria Antitoxin, the serum of a horse or other large domestic animal immunized by the injection of diphtheria toxin. The fluid must have a potency of at least 250 units per mil, and must be kept in sealed glass tubes in the dark and at a low temperature. It is a yellowish fluid, often slightly turbid, and with a slight odor of an antiseptic. Each tube bears a label giving the number of antitoxin units contained, the date at which the serum was tested, and the date beyond which it will have deteriorated appreciably. Average hypodermic or intramuscular dose, 10,000 units; prophylactic dose, 1000 units. This dose may be repeated after twenty-four hours if necessary. Antitoxic serum slowly loses its power and should not be used if more than a year old.

The antitoxin of the serum is precipitated along with the globulins when such neutral salts as ammonium sulphate are added, and the precipitate may be redissolved by dialyzing off the excess of salt. In this way a more con-

centrated and purer solution may be obtained; and many such preparations are on the market under such designations as "concentrated," "purified," or "refined" diphtheria antitoxin. They have the advantage that less fluid has to be injected than if the serum is used.

Serum Antidiphthericum Purificatum (U. S. P.), a solution in physiological salt solution of antitoxin each mil containing 250 units. Dose, the same as that of the ordinary serum.

The serum may be dried by evaporation at low temperature without losing its antidiphtheritic properties, and in this form it has less tendency to deteriorate.

Serum Antidiphthericum Siccum (U. S. P.) is prepared from either the ordinary serum or the purified one and contains 4000 units per gram. It is soluble in nine parts of distilled water with which it forms an opalescent viscous fluid; a more satisfactory solution is formed if more water or salt solution is used. The solution must be used at once.

The use of this serum has revolutionized the treatment of diphtheria, and has reduced the mortality in this disease to about one-third or less of that prevailing before Behring introduced the method in 1893. The symptoms improve within 24 hours, the course of the disease is cut short, and there is not the fatal tendency to spread to new surfaces which was formerly seen. It is not yet determined how far the diphtheria paralysis is prevented by the serum. The serum has no direct action on the bacilli of diphtheria, but it antagonizes the toxin formed by them and thus prevents the death of the cells on which the bacilli are growing; these protected cells then overcome the invaders and the local lesion therefore improves rapidly.

The remedy must be applied immediately, for when the tissues have been exposed to the toxin for some time and it has combined with the cells, the antitoxin has much less antidotal effect. For example, the prognosis is about four times as bad if antitoxin is injected on the third day as if it had been used on the second day of the disease. It is also effective as a prophylactic for those exposed to the infection. The antitoxin must be injected subcutaneously or intramuscularly in large quantities, and it is desirable to have a serum containing a large number of units, because a weak serum can only be effective if injected in large doses, and these tend to induce skin eruptions and other unpleasant features. Only a few c.c. of a strong serum are necessary, and these do not contain enough of the foreign components to cause these symptoms. In severe cases the serum may be injected intravenously; it has no action when taken by the mouth.

Antitetanus Serum.

The tetanus bacillus forms a toxin which induces powerful tetanic spasms from an action on the spinal cord similar to that of strychnine. These may be elicited by the injection of the toxin and also arise from its absorption from wounds infected with the bacillus. An antitoxin is formed by immunizing horses in the same way as the antitoxin of diphtheria poison, and this injected into animals protects them from tetanus toxin. In tetanus infection from wounds, however, the toxin reaches the spinal cord, not through the lymph and blood-

vessels, but by travelling along the nerve fibres, while the antitoxin circulates in the blood and reaches the nerve fibres and cells with difficulty (Meyer and Ransom). There is thus little opportunity for the neutralization of the toxin except that circulating in the blood, and the results of treatment with this serum are much less striking than those of the antidiphtheritic serum. But if the serum can be injected early, before the spinal cord has been attacked by the toxin, its effects are specific, and it is therefore used as a prophylactic in cases where tetanus infection is probable, and with the best results. When symptoms are already present, the antitoxin is of little value if given subcutaneously or even intravenously, and this has led to its being injected into the subarachnoid space, with it is reported, good results.

The antitetanus serum is standardized in the same way as the antidiphtheria serum and should not be used when more than a year old.

The U. S. P. contains tetanus antitoxin in three forms corresponding to those of diphtheria antitoxin.

Serum Antitetanicum, the serum of an animal immunized against tetanus toxin having a potency of 100 units per mil.

Serum Antitetanicum Purificatum, formed from the first preparation and of the same strength.

Serum Antitetanicum Siccum, the dried serum or purified serum, containing 1000 units per gram.

The pharmacopœia recommends as an average dose for hypodermic injection 10,000 units for treatment and 1500 units for prophylaxis. But smaller quantities are often effective.

Antimeningitis Serum.

Cerebrospinal meningitis is due to an infection with Weichselbaum's Diplococcus intracellularis, and a serum has been prepared by treating horses with the toxins of these organisms, and later, when a partial immunity has been reached, by infecting them with the living microbes. The serum is then obtained in the same way as the antidiphtheritic serum. This serum has been injected subcutaneously in cerebrospinal meningitis, but the best results are obtained by its injection into the spinal canal. Dose, 10–15 c.c. or more. The mortality of this form of meningitis has fallen materially since this treatment was instituted by Flexner.

Antivenin.

The poisons secreted by the poisonous snakes contain toxins, and an antitoxic serum prepared by Calmette has been termed antivenin. It protects animals against a dose of snake poison which would otherwise be fatal and has also been used with success in snake bite in man. But the effects of snake bite manifest themselves so rapidly that there is not the same opportunity of using this serum as there is in the case of diphtheria, and it is found that the serum is unable to neutralize the toxin unless they are injected almost simultaneously. And the poison of different species of snakes varies in composition to some

extent. When the antivenin is available, however, its injection should certainly form part of the treatment of snake bite.

Many other immune sera have been proposed, but as yet none of them have been generally accepted as of value. Toxins are found in many other animal poisons, such as those of the spiders, scorpions, bees and fish. They also occur in some of the higher plants and are then termed phytotoxins.

Ricin is an intensely poisonous albumin found in the seeds of Ricinus communis along with castor oil, which does not itself contain this principle, however. Ricin is poisonous in doses of about $\frac{1}{1000}$ milligram per kilogram body weight injected subcutaneously, but seldom causes any symptoms when swallowed, as it is apparently destroyed for the most part by the digestive ferments. It is thus among the most powerful of the vegetable poisons when it is injected subcutaneously. Death often occurs only several days after the injection in animals, and in the interval no symptoms make their appearance except some loss of appetite, and toward the end, diarrhœa and vomiting. Post-mortem, the bowel is found inflamed and congested and contains ecchymoses; blood is found in the serous cavities, and extravasations may occur in various other organs, although not so uniformly as in the bowel. Among the most obvious lesions are the innumerable ecchymoses in the great omentum and the swelling of the abdominal lymph glands, which generally contain numerous small hæmorrhages. Microscopical examination reveals small foci of necrosed tissue in the liver, spleen, intestine, stomach, and other organs. Ricin seems to be excreted by the intestinal epithelium, which may explain the violence of its action here, although it acts as a poison in many other tissues. It is a powerful irritant, inducing inflammation and suppuration when it is injected subcutaneously, or is applied to the conjunctiva. On the other hand it has little or no irritant action on the mouth and throat, and is digested and rendered harmless in the stomach. The mucous membrane of the nose is irritated by the inhalation of the powder in many persons. This toxalbumin has a very characteristic action on the blood. When a drop of a dilute solution is added to a test-tube of defibrinated blood, the corpuscles soon fall to the bottom, leaving the clear serum above, and the blood does not filter through paper any longer, the corpuscles all remaining on the filter, the serum passing through colorless. This is due to the agglutination of the red cells, which are formed into masses and thus fail to pass through the pores of the filter. Fibrin does not seem to be formed in the process, as was at one time supposed, but the nature of the cementing substance is unknown. Stillmark supposed that ricin formed these masses of red cells in the bloodvessels, and that the symptoms were due to the emboli resulting, but this is certainly incorrect, for the blood of immune animals reacts in the same way, yet these are not poisoned by many times the usual fatal dose of ricin.

Ehrlich found that animals rapidly acquire immunity to the action of ricin, if they receive for some time small non-toxic doses. From this discovery has arisen the Ehrlich side-chain theory, which plays such an important rôle in medicine at the present time. By gradually increasing the daily amount of ricin, rabbits have attained an immunity of 5000, that is, they are not affected by 5000 times as much ricin as would have killed them had no preliminary treatment been instituted.

Ricin and its antitoxin are not used in therapeutics, but ricin has repeatedly given rise to poisoning, from the beans being taken as a substitute for the oil. Cattle have also been poisoned by being fed on the refuse of castor oil beans after the oil had been expressed.

Another vegetable toxin which resembles ricin very closely in its effects is **Abrin**, which is obtained from the seeds of Abrus precatorius or jequirity, the familiar scarlet and black beans, which are often formed into necklaces. Abrin contains two poisons, a globulin and an albumose, of which the former

is the more powerful. It induces the same symptoms as ricin, but is less poisonous, and immunity can be acquired in the same way. Animals which are immune to ricin are not more resistant to the action of abrin than others, because the two poisons form different antitoxins. Abrin or jequirity has been used as an irritant to the eye in cases of granular lids and of corneal opacities. It causes an acute inflammation which improves the condition in some cases, but it must be regarded as an exceedingly dangerous remedy, as the inflammation is entirely beyond the control of the surgeon. In animals the eye is often completely destroyed by the application of abrin, while in other experiments enough of the drug is absorbed to cause fatal poisoning.

Crotin is another toxin, which is found in the Croton Tiglium, but which does not pass into croton oil. It is less poisonous than ricin and abrin, but resembles them in most other points, except that it does not cause agglutination of the blood cells of certain animals, while ricin and abrin have this effect in all kinds of blood hitherto examined.

XXXIV. VITAMINS, OR ACCESSORY FOOD SUBSTANCES.

Vitamins are substances which must be supplied in small quantities to maintain normal health; if one of them is inadequate, the deficiency leads to the development of disease and death or permanent impairment; but if the lacking constituent of the dietary is given before irretrievable damage has occurred in the tissues, complete recovery generally follows. The amount of these substances necessary to maintain health is so small, that they cannot be regarded as sources of energy like the ordinary foods, but must resemble drugs in their method of action, exactly as adrenaline or thyroid preparations which form the nearest analogy with them.

The fact that small quantities of apparently indifferent substances are necessary to health was first appreciated a century and a half ago, when it was noted that scurvy could be cured by fresh vegetables or by the juice of lemons and other similar fruits. More recently it was discovered that beri-beri, a disease which is seen chiefly in rice-eating countries, and which became very prevalent when polished rice was introduced, could be remedied by treating the patients with less completely prepared rice or with the germ which had been removed in the process of polishing. But the subject only received the attention it deserved when it could be accurately examined by means of animal experiments. At the same time it became clear that in modern urban populations and with the present methods of preserving and storing foods there is a danger that these and other "deficiency diseases" may become more prevalent than has hitherto been the case; many people consuming food adequate as far as the provision of energy is concerned live on the borderline below which the vitamins are deficient and ill-health results. For man, like the other animals, cannot manufacture those essential substances, but derives his supply from vegetables either directly or through the flesh of animals which have absorbed them in their food. Nursing infants draw their supply of vitamins from the mother's milk, and a deficiency in her food often gives rise to symptoms in the child; these disappear at once on supplementing the mother's diet where necessary.

Three vitamins are recognized at present, but it is not unlikely that there may be others or perhaps that some of those now recognized may prove to contain two or more different principles. None of the vitamins have been isolated, and little is known of their chemical or physical characters, as they are unstable, readily destroyed by oxidation and often by heating, or even by keeping. None of them have any positive action in the body, as far as is known, when given in excess; but deficiency in their supply gives rise to symptoms which are relieved by their administration.

Vitamin A is soluble in fats and oils and may be a lipoid itself. It is the most stable of the three known vitamins, resisting boiling temperature and oxygen and only slowly disappearing on keeping. It is found in green plants, which are able to form it, and in the fats of animals which have obtained it from green plants; it is present in abundance in milk, egg-yolk, and especially in cod-liver oil. Its solubility in fats apparently leads to its being stored in the body to a greater extent than the other vitamins, so that symptoms do not arise early from deficiency unless there is a special call for this vitamin, such as occurs in young growing animals or during pregnancy. Its presence in the food is necessary for the growth of young animals and in its absence animals of all ages become more susceptible to infection and especially to affections of the eye, which are known as xerosis and keratomalacia and which result in perforation of the eyeball; even when the supply is sufficient to avert these, the power of reproduction is lowered. Vitamin A then appears to act on the general nutrition of all the cells in the body. It has been stated that its deficiency in the food is the cause of rickets, and there is evidence that foods rich in it cure certain cases of this disease; but the exposure of the patient to sunlight or ultraviolet light and fresh air is equally efficient, and the relation between these treatments is not yet clear. The presence of vitamin A in a food or dietary can only be ascertained by experiments on animals, and these are best performed on young rats; the dietary is made up without vitamin A and when growth ceases and symptoms of malnutrition appear, the food to be tested is supplied to supplement the dietary and its success in abating the symptoms determines its content of this essential body. The importance of an adequate supply of vitamin A is very great, especially for young children. It is best supplied in the form of milk and butter from grass-fed cows, and if necessary as cod-liver oil. Adults require less and may supplement or replace these sources by the use of green vegetables.

The value of cod-liver oil in malnutrition in the young and in rickets has long been recognized, but has only recently been attributed to the presence of this essential substance. Previously various theories of its action were suggested and many substitutes were devised and made from vegetable oils; but the vegetable oils are almost devoid of vitamin A, and these substitutes are valueless.[1] Cod-liver oil itself may be reduced in efficiency by elaborate refinement, but attention is now being paid to

[1] In the same way butter substitutes made from vegetable oils cannot replace butter as far as the vitamin is concerned.

preserving the vitamin, while eliminating the repulsive odor and taste which characterized the original vitamin-rich preparation.

Cod-liver Oil or Oleum Morrhuæ (U. S. P., B. P.) is given in doses of a teaspoonful or dessertspoonful once or twice a day, as the patient can be induced to take it. Some children take the oil alone without difficulty, while others find a flavored emulsion more palatable.

Vitamin B, or antineuritic vitamin, is soluble in water and alcohol, while it is insoluble in fats and oils. It is readily adsorbed by charcoal and diffuses slowly through membranes, which shows that its molecule is large but smaller than that of the typical colloids. It is less stable than vitamin A, but withstands boiling for a short time. It is found in most forms of plant life, but is concentrated in the germ of seeds, in yeast and in eggs; other animal foods contains only small quantities. Its presence in seeds provides an abundant source, but the ultra-refinement of modern foods tends to remove the vitamin along with the germ, and white bread and polished rice contain little or none. Vitamin B, being water soluble, is not stored in the tissues like vitamin A, and a deficiency in it elicits symptoms rapidly.

A diet providing insufficient vitamin B leads to malnutrition and retarded growth, but the most characteristic effect is the occurrence of polyneuritis, with the usual histological appearances in the nerve trunks. These symptoms (beri-beri) have been observed repeatedly in epidemics in man from the use of polished rice or white bread as the chief constituent of the dietary. Deficiency of the vitamin B is best recognized by feeding pigeons on the diet, when polyneuritis sets in in the course of about three weeks and soon proves fatal. When polyneuritis has been induced in pigeon or man, the supply of a food rich in vitamin, such as whole wheat bread or rice polishings is followed by rapid recovery. While the nerve symptoms are the most striking features, they are accompanied by some changes in the general nutrition often shown in œdema.

Vitamin C, or the antiscorbutic vitamin, is soluble in water and alcohol, diffuses through parchment and is not readily adsorbed; it is the most unstable of the three, disappearing on being heated to about 60° C., and rapidly undergoing deterioration on keeping. It is found in growing plants and is mainly supplied in the form of potatoes, fruits, and fresh green vegetables. It is most abundant in the juice of oranges, lemons and allied species. It is to be noted that much of the vitamin is destroyed by the ordinary methods of cookery and preservation and that a diet apparently containing a fair amount of vegetable food may be rendered insufficient through the methods of preparation and storage. Dried grains and seeds contain only traces, but if they are allowed to germinate the vitamin is developed, and in case of necessity growing malt or peas may be used to supply it. The most convenient method of transporting it is in the form of lemon juice, which retains its virtues for a long time, even when dried. Like vitamin B, it is not stored in the tissues and a more regular supply is necessary than of A. Deficiency in vitamin C, leads to malnutrition with loss of weight and culminates in the symptoms of scurvy, which was formerly prevalent in long voyages when fresh

vegetables were unobtainable, and which still occurs occasionally in urban populations from neglect and ignorance of the value of fresh vegetable food. In scurvy the chief lesions begin along the alimentary canal, and apparently arise from injury to the capillaries and arterial walls which leads to exudations and hæmorrhages. They occur in the guinea-pig readily and this animal is the most suitable for the investigation of deficiency of vitamin C.

XXXV. SOME MINOR POISONS.

1. Nitrobenzol Compounds.

The nitrobenzol bodies are chiefly of interest because they have often given rise to poisoning of late years from their use as explosives, in chemical manufactures, and to flavor alcoholic liquors. They are readily absorbed from the skin and serious symptoms have followed the wearing of clothing dyed with them. In man nitrobenzol causes a grayish-blue, cyanotic color of the skin and visible mucous membranes, often with nausea, vomiting, great muscular weakness, marked dyspnœa, delirium, and some convulsive movements of the face and jaws, less frequently of the whole body. Total unconsciousness and coma are followed by arrest of the respiration.

These effects are due in part to changes in the blood, in part to central nervous action, in which stimulation and paralysis seem to follow one another. The blood is found of a chocolate-brown color, and some of the red cells are either deformed or entirely destroyed. Examined with the spectroscope, methæmoglobin is very often found in it, while in other cases an absorption line is observed between the yellow and the red, which does not seem to correspond to that of any of the ordinary hæmoglobin products, and has therefore been called the nitrobenzol-hæmoglobin line. The blood contains a much smaller amount of oxygen than normally, in some cases only 1 per cent. instead of 17, and artificial respiration or even shaking the blood in air fails to oxidize it further, as the combination of nitrobenzol and hæmoglobin seems to be incapable of absorbing oxygen. Similar changes may be produced in venous blood outside the body by shaking it with nitrobenzol. These changes in the blood are the cause of the cyanosis, and the imperfect oxidation of the tissues leads to the appearance of a number of abnormal products in the urine, such as hæmatoporphyrin. In animals a gastro-intestinal catarrh is almost constantly produced unless the intoxication is very acute, and this occurs even when the poison is inhaled or injected subcutaneously.

Metadinitrobenzol ($C_6H_4(NO_2)_2$) has repeatedly given rise to poisoning in the manufacture of the modern explosives, such as roburite and securite. In action it resembles nitrobenzol, but is more poisonous, and the gastric symptoms are more marked. Amblyopia and jaundice-like coloration of the skin often occur from prolonged exposure to this poison.

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2. Toluylendiamine.

Toluylendiamine ($C_6H_3CH_3(NH_2)_2$) has never been used in therapeutics, but it is of importance from the light which it has thrown on some forms of jaundice. Stadelmann found that its administration in dogs produced the typical symptoms of icterus, while in cats the icterus was less marked, but very large quantities of hæmoglobin were excreted in the urine. The explanation of this action is the destruction of the red cells in the blood, which leads in the dog to the formation of large amounts of bile pigments in the liver. Some of this pigment is reabsorbed from the bile vessels and leads to typical jaundice. The absorption is promoted by a curious increase in the mucus secretion of the bile ducts, which renders the bile more viscous, and by thus delaying its evacuation into the intestine favors its absorption into the blood. This increased mucus formation is believed to be due to the action of the poison on the secretory cells of the larger bile ducts. The formation of bile pigment from hæmoglobin liberates large quantities of iron, which seems to be stored in the liver, spleen, and bone marrow. In the cat the hæmoglobin is not so largely formed into bile pigment, but escapes in the urine. In both animals some methæmoglobin is probably formed.[1] According to Joannovics and Pick the hæmolysis is not directly due to the toluylendiamine, but is the result of bodies formed in the liver under the action of the poison.

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3. Benzene.

Benzol, or benzene, is much less poisonous than its hydroxyl compounds, but may give rise to symptoms resembling those of phenol when it is inhaled in large quantities. It was at one time suggested as a general anæsthetic, but the preliminary excitement is much greater than that seen in the use of chloroform or ether, and partakes more of a convulsive character. Even after unconsciousness and anæsthesia is attained, the characteristic muscular tremor of the aromatic compounds continues. In some animals it produces violent and prolonged convulsions, with only partial loss of sensation, and even large quantities do not cause the complete relaxation of the muscles requisite for surgical operation. It seems to have little or no irritant action on the alimentary canal or kidneys in animals, and is excreted in part by the kidneys as phenol double sulphate, in part unchanged by the lungs.

Santesson states that hæmorrhages occur very frequently in fatal poisoning in man, and found the same result in experiments on rabbits; he ascribes it to fatty degeneration of the arterial walls, which was well-marked in most of his experiments. A number of cases of fatal intoxication are on record, some of them arising from the drug being swallowed by suicides, but most of them from the accidental inhalation of large quantities in india-rubber factories. Animals exposed to benzene vapor do not seem to absorb enough to be seriously poisoned, but when it is injected subcutaneously or applied over a large skin area, it proves fatal to them. It has recently been noted that in benzene poisoning a marked fall in the number of the leucocytes of the blood occurs and this has suggested the use of benzol in some forms of leucæmia; a great diminution in the

[1] A somewhat similar action follows the administration of Cephalanthin, the active principle of Cephalanthus occidentalis, Button-bush or Swamp dogwood (Mohrberg), and of the alkaloids of several species of Senecio such as ragwort and groundsel.

white cells follows and the general symptoms show a corresponding improvement. It is too soon to state how far the treatment leads to permanent relief, or how long it may be continued.

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4. Phlorhizin.

Phlorhizin is not used in therapeutics, but has attracted some attention from its effects in animals, and may therefore be mentioned shortly. It is a glucoside ($C_{21}H_{24}O_{10} + 2H_2O$) found in the rootbark of the apple, pear, cherry and plum tree. When given in large quantities by the mouth it sometimes causes some diarrhœa in animals, but apart from this its only effect is glycosuria, which also follows its injection subcutaneously or intravenously. The urine is found to contain 5–15 per cent. or even more of sugar, sometimes along with acetone and oxybutyric acid, so that the intoxication seems at first sight to resemble diabetes mellitus in man very closely. Phlorhizin induces the same results in man, and the glycosuria is not accompanied by any other symptom generally. It differs from true diabetes, however, in the fact that the sugar of the blood is not increased in amount. The glycosuria is not due to any change in the general metabolism of the body, therefore, but to some alteration of the renal epithelium, by which the blood sugar escapes into the urine, instead of being retained in the body and used as a source of energy. This has been definitely proved by Zuntz, who showed that when phlorhizin was injected into one renal artery, the urine secreted by the corresponding kidney contained sugar, while that from the other remained normal for some time. As the available sugar is drained off in the urine, the tissues rapidly manufacture more and pour it into the blood. As long as sufficient food is given, the loss of sugar does not seem to entail any increase in the destruction of the protein tissues, but when phlorhizin is given to starving dogs, the waste of sugar has to be made up from the tissues, and the nitrogen of the urine accordingly rises in amount, while at the same time the liver cells become infiltrated with fat globules. The statement that the sugar of the milk is increased by phlorhizin has proved to be incorrect.

Glycosuria may be maintained for an indefinite time if the administration of phlorhizin be continued, and animals recover rapidly when the treatment is stopped. The glucoside is probably excreted in the urine unchanged, although this has not been quite satisfactorily demonstrated as yet. Phlorhizin may be decomposed into a sugar, phlorose, and phloretin, which also induces glycosuria.

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XXXVI. SODIUM CHLORIDE AND WATER.

The most typical example of salt-action (page 25) is presented by chloride of sodium, for this salt is always present in large quantities in the body, and has practically no specific action; the sodium and chloride ions are ordinary and necessary constituents of the fluids of the body.

The action of this salt is therefore limited to the alteration in the physical properties of the fluids, which its presence in excess or in limited amount induces. In the same way the action of water is due only to its diluting the body fluids and lessening their osmotic pressure, and it may therefore be described along with that of salt.

Most of the tissues hitherto examined in regard to this point have proved permeable by both the Na and Cl ions, but in every case there is a certain amount of resistance offered so that the presence of salt in the fluid round a cell always prevents water from diffusing freely into the interior; *i. e.*, sodium chloride solution exerts osmotic pressure on the cell. The molecular weight of common salt being small, the osmotic changes induced by it are greater than those induced by an equal weight of most other salts, because a larger number of molecules exist in each gramme. It also dissociates into its two ions more readily than many others, and this lends it still greater osmotic power.

A common example of the osmotic action of salt is seen in its use to preserve meats from putrefaction, which it accomplishes by withdrawing the fluids of the meat, and thus rendering it dry and hard and unsuitable for the growth of microbes.

In the same way the **Red Blood Corpuscles** shrink in size when they are placed in a solution of salt which is stronger than the blood-plasma (hypertonic), because the water is withdrawn from them. In dilute (hypotonic) solution, on the other hand, or in water, they swell up because they absorb water, while in solutions of the same osmotic pressure as the plasma (isotonic) they remain unaltered in size. When water is absorbed into the corpuscles, they swell up and burst, and the hæmoglobin diffuses into the surrounding liquid.

Muscle is affected in a similar way, strong salt solutions withdrawing fluid from it, while weaker ones are absorbed, and both tend to destroy its vitality in a longer or shorter time. In isotonic salt solution, on the other hand, muscle preserves its irritability for many hours. Strong salt solutions irritate exposed **Nerves** from the withdrawal of their fluid contents, and on the other hand, distilled water first irritates and then paralyzes them.

These changes are undoubtedly due to the imperfect permeability of the cells by the sodium and chloride ions, and as regards the red blood corpuscles, it is definitely known that salt penetrates them with great difficulty, and the changes induced in them by salt solutions of different concentration and by water are due to the alteration of their fluid contents only. If this were true for all cells, the isotonic solution would preserve them in a normal condition until they slowly perished for want of oxygen and from exhaustion of their reserve of food. But this is found not to be the case, for muscle suspended in isotonic solution often develops a more or less rhythmical series of contractions, while the frog's heart ceases to beat after a time when it is perfused with isotonic salt solution, although it has not exhausted its energy entirely. Similarly some ova and fish living in sea water die if they are put in a solution of sodium chloride isotonic with sea water, while they live much longer in distilled water. It is obvious that in these instances no change in the distribution of the fluids can occur, for the osmotic pressure of the fluid is unchanged. In other words the

death of these animals in pure salt solution is due, not to the physical action of the salt (salt action), but to the sodium ion exercising a deleterious effect on them. This deleterious action may be neutralized by the addition of traces of salts of calcium or of some other bivalent elements, while the monovalent kations have less antagonistic effects (Loeb). In the natural environment of living cells both sodium and calcium are present, so that the toxic effect of sodium (see Calcium) can scarcely be observed except when small masses of tissue are thoroughly washed with salt solution; as far as the higher animals are concerned, then, salt may be regarded as indifferent in itself and as acting only through changing the distribution of the fluids. And as isotonic solutions have no osmotic action, they are entirely inert.

Water or very dilute salt solutions penetrate into the superficial cells of the **Skin**, which therefore become swollen and softened. Concentrated solutions, on the other hand, rather tend to draw fluid from the surface cells, and this along with the passage of salt into them, causes some mild irritation. Neither salt nor water is absorbed into the circulation through the skin in mammals. A much greater absorption into the superficial tissues occurs on less protected parts, such as the cornea, which becomes white and clouded when strong salt solutions are applied to it. Similarly, either pure water or strong salt solution causes considerable pain and smarting in the nasal passages, or in wounds, from the disturbance of the normal relation of salt and fluid in the surface cells. Isotonic solutions, on the other hand, cause no pain.

In the **Mouth** salt has a characteristic taste, and strong solutions act as astringents here and in the throat. In the **Stomach** its action is very much like that on other mucous membranes, hypotonic solutions causing swelling, while hypertonic solutions cause a withdrawal of fluid and a shrinking of the cells. This withdrawal of fluid and imbibition of salt may set up such irritation as to induce vomiting; apparently the greater the penetration of a salt the greater the tendency to cause vomiting, for ammonium chloride is more powerful than sodium chloride and this more than sodium sulphate.

The digestion in the stomach does not always seem to be improved by salt in the food, for even small quantities have been found to lessen the acidity of the gastric juice, and the amount of albuminous food absorbed from the alimentary canal in animals is but little altered when salt is added to the food. It is very possible, however, that a small quantity of salt in the food renders it more palatable in many instances, and thus increases the reflex flow of the gastric juice. (Compare Simple Bitters.) Dapper finds that the hydrochloric acid of the stomach is increased in some persons and diminished in others by mineral waters containing common salt as their chief ingredient. These waters have no effect on the secretion directly, then, but may alter it by changing the nutrition of the gastric mucous membrane, or by arousing secretion reflexly by their taste.

Salt solutions are **Absorbed** little in the stomach, largely in the bowel, but considerable difference of opinion exists as to the means by which this is accomplished. An attempt has been made to explain absorption by the action of the known physical processes, such as

diffusion, osmosis and filtration, but these seem quite inadequate without the assumption that there is a constant tendency for fluids and for some salts to pass inward from the lumen of the bowel. This tendency may be opposed or strengthened by the osmotic pressure. Thus hypotonic solutions and water are absorbed rapidly, because here not only is the natural flow inward, but the osmotic current is in the same direction, the fluid being of lower osmotic pressure than the blood serum. In solutions of equal osmotic pressure with the blood serum the absorption is slower, because here the natural flow alone is active, while hypertonic solutions are still more slowly absorbed or may even be increased at first, because the osmotic pressure acts in the opposite direction from the natural flow. Accordingly, while hypotonic and isotonic solutions disappear rapidly, the absorption of the stronger solutions may be preceded by a period in which the fluid of the bowel actually increases, water diffusing into it from the blood. At the same time the salt is being absorbed and the solution eventually becomes isotonic and is absorbed.

The **Blood** and **Lymph** are in turn affected by these processes. When hypotonic solutions pass into the blood from the bowel, the proportion of solids and liquid is of course changed and fewer corpuscles and less solid matter are found in the cubic millimeter than normally (hydræmia). On the other hand, when strong salt solutions in the bowel cause the effusion of fluid, the blood becomes more concentrated than in ordinary conditions. After the reabsorption of the fluid, the normal balance of plasma and corpuscles must be restored, and to effect this currents are set up between the blood and the fluid of the surrounding lymph. These currents have been investigated by the injection of salt solutions directly into the blood, and not by their absorption from the bowel, but the processes probably resemble each other in their chief features. When the blood is rendered hypertonic by the injection of strong salt solution, the lymph at once begins to pour into the bloodvessels by osmotic attraction and this leads to hydræmia and increased capillary pressure, the arterial tension remaining unchanged. This augmentation of the capillary pressure in turn induces a flow of lymph from the bloodvessels into the lymph spaces.

The flow of lymph from the bloodvessels is therefore first diminished in amount by the presence of salt in the intestine and blood and then increased again by the high capillary pressure. This interchange between the blood and lymph is continued, because as the salt is excreted by the kidneys and other excretory glands, a continual variation in the osmotic pressure of both blood and lymph occurs.

The details of the changes between the blood and lymph under the action of salt and water are still obscure, but there is no question that the absorption of either of these leads to an augmentation of the normal exchange of these fluids. In particular, it is still undecided whether the cells of the vessels possess a secretory function similar to that of the secretory glands, or whether the whole process may be attributed to variations of osmotic pressure and filtration.

The changes in the blood and lymph are followed by an increased activity of the **Excretory Organs.** Thus the urine[1] is much augmented by the injection of salt solution into the blood, less so by the absorption of water or salt solution from the stomach and bowel. The presence of salt or water in the blood in excess leads to increased interchange of water between the tissues and blood and the latter becomes diluted, that is, contains a lower percentage of colloids than normally. This reduces the osmotic resistance to filtration, so that a more abundant flow occurs through the glomerular capsule into the tubules. Here water and salt are absorbed in certain definite proportions; if the salt is present in the filtrate in higher proportions than normally, it is rejected by the epithelium of the tubules and finds its way into the ureters, while if the proportion of salt is low, some of the water fails to be taken up and similarly passes out as urine. The increased glomerular filtrate contains more urea, phosphates and other constituents which are not absorbed in the tubules, and the amount of these in the urine is thus increased, though their percentage may fall. Cow has recently pointed out that when water is injected intravenously or hypodermically, it has little diuretic action; this arises from the cells of the blood and subcutaneous tissues at once taking up the water, so that it disappears from the circulating fluids, to which it is only restored slowly and gradually.

When very large amounts of isotonic salt solution are thrown into the blood, the organism may have difficulty in excreting it rapidly enough, and the tissues are therefore found to be swollen and œdematous in some parts of the body.

When salt solution is injected into the serous cavities or into the lymph spaces, absorption occurs in the same way as from the alimentary canal, except that in the case of the serous cavities diffusion seems to play a greater, and the other forces a smaller rôle, than in the stomach and intestine.

The administration of large quantities of fluid, either as water or as dilute salt solution, might be expected to have some effect on the general **Tissue Change,** through the increased movement of the lymph flushing out the cells and leading to a more complete removal of the waste products. As a matter of fact, some increase in the nitrogen and sulphur eliminated in the urine has been observed under the use of large quantities of water, but it is impossible to estimate at present how far this may be due to the diuresis alone; in any case the increase is not by any means so large as is often believed, as it only amounts to some 5 per cent. or less. Any salt solution causing an acceleration in the movement of the fluids of the body must tend to facilitate the excretion of the waste products in the same way, but some recent investigations indicate that in addition salt tends to alter the protein

[1] The following explanation of the diuresis is based upon the theory that all the constituents of the urine are filtered off by the glomerulus, and that some of them, notably much of the fluid and the alkali chlorides, are reabsorbed in passing through the tubules See "Secretion of the Urine," 1917.

metabolism through acting directly on the cells; this action is so slight, however, that the resulting change in the nitrogen eliminated is concealed by the increase caused by the more complete flushing and diuresis. The amount of proteins and fats absorbed from the alimentary tract does not appear to be altered by the administration of large amounts of water (Edsall).

Strong salt solutions injected into animals either hypodermically or intravenously sometimes prove fatal, apparently from the withdrawal of fluid from the central nervous system. The symptoms in mammals are increasing lassitude and weakness, with augmented reflex excitability, tremors, and finally convulsions. The circulation is only slightly affected until just before death, when the blood-pressure falls suddenly. The red-blood cells are found to be much shrunken, and hæmorrhages are found in different organs; the lungs are œdematous, and the intestinal mucous membrane is swollen and congested.

The **Salts of the Urine** are increased by diuresis from any cause, as has been stated; both sodium and potassium are augmented, but especially the sodium, which is present in larger proportions in the plasma and therefore forms a larger constituent of the glomerular secretion. This increase in the sodium salts is, of course, particularly marked when diuresis is induced by common salt, but when potassium salts increase the urine, the sodium also generally predominates in it and this would eventually lead to the loss of all the sodium in the blood of herbivora, whose food contains large quantities of potassium; but after a certain amount of sodium has been lost, potassium causes no further excretion, so that the tissues are protected from the total loss of sodium chloride, which would be fatal to them.

Bunge states that in both man and animals a diet rich in potassium causes an appetite for common salt, while a diet which does not contain an excess of potassium does not develop this desire. Thus herbivorous animals and agricultural peoples seek for salt, because vegetable foods contain large quantities of potassium, while the carnivora and the hunting peoples require no salt and often have a distaste for it, owing to their food containing a larger relative proportion of sodium salts. This instinctive appetite he regards as a means by which nature protects the tissues from excessive loss of sodium. Some doubt has recently been thrown on this explanation of the desire for salt by Lapicque, who discovered some African races living on vegetable substances alone, and using the ashes of the plants, which contain more potassium than sodium, as civilized peoples use ordinary salt. He holds, therefore, that salt is merely of value as a flavoring agent.

Therapeutic Uses.—Water and salt are rarely or never prescribed as such, but are used to a very large extent in medicine, and great virtues have been ascribed to them in a number of pathological conditions.

They are used for their local action, and for the supposed alterations in the tissue-change and in the excretions produced by them after their absorption into the blood. In general, patients are sent to watering places and baths, where, as Sir Walter Scott says, "the invalid often finds relief from his complaints, less from the healing virtues of the spa itself, than because his system of ordinary life undergoes an entire change, in his being removed from his ledger and account books from

his legal folios and progresses of title deeds -from his counters and shelves– from whatever else forms the main source of his constant anxiety at home, destroys his appetite, mars the custom of his exercise, deranges the digestive powers, and clogs up the springs of life." At the same time the drinking of large quantities of weak salt solutions, and the constant bathing in somewhat irritating fluids, may exercise a therapeutic action in many cases, and may at any rate aid the hygienic conditions. Whether the water contains salt or not, it must be remembered that in bathing the action is a purely local one, for neither the salt nor the water is absorbed. The slightly irritant effect on the skin may, however, improve its circulation and nutrition, and thereby be efficacious in some skin diseases. By continued use the sensitiveness of the skin vessels to heat and cold may also possibly be deadened. The changes in the metabolism induced by bathing in strong salt solution are merely trifling. Special baths are very frequently recommended for some diseases, probably without justification; the greater the concentration, the greater is the effect on the skin, and it is of no importance which of the neutral salts is in the solution, or whether small traces of iron or other metals are present; alkaline baths act more on the skin than others.

In diseases of the stomach the drinking of large quantities of water or of weak salt solutions may also be beneficial. The action is similar to that on the skin—a mild irritation, owing to the swelling of the more superficial cells of the epithelium and the increased movement of the fluid in them and in the deeper layers. In some cases of insomnia hot water sometimes causes sleep, probably by causing dilatation of the gastric vessels, and thereby withdrawing the blood from the brain.

In many diseases in which the symptoms point to a disorder of the metabolism, water and salt solutions are advised. Thus gout and rheumatism are frequently treated by sending the patient to watering places, on the theory that the tissues are washed out thoroughly and the waste products thus removed. As a matter of fact, the more recent work in this direction shows that large quantities of water and dilute salt solutions have little or no effect on the uric acid excretion, which was formerly believed to be much diminished. This fact does not necessarily involve the inference that the treatment is erroneous, for it is now generally recognized that gout is not really due to the failure of the uric acid excretion. Many cases are unquestionably benefited by the springs, although it may be questioned how much of the improvement is due to the water taken, and how much of it ought to be ascribed to the changed conditions of life.

The bath treatment has been recommended for numerous diseases in which the salt and water could not possibly have any beneficial action, and in which the remedial agent is the climate, and perhaps the faith of the patient in the water. Belief in the healing power of certain natural waters is one of the most ancient of all therapeutic theories, is found among altogether uncivilized peoples, and has been incorporated in many religions. It is not to be wondered at that in

some nervous disorders the faith of the patient and auto-suggestion perform some marvelous "cures."

In obesity the drinking of some waters, such as those of Kissingen and Homburg, has been advised. These waters contain from 0.2–1.4 per cent. sodium chloride, and it seems very doubtful if they have any effects in themselves; many hold that the benefits accruing from the treatment are really due to the hygienic measures followed, and that the waters play only an insignificant rôle.

Salt in solid form or in strong solution is used occasionally as an emetic in cases of emergency, as in poisoning, and generally produces vomiting rapidly, owing to the irritant action on the stomach. In nitrate of silver poisoning it arrests the corrosive action by the formation of the insoluble silver chloride.

Salt solution is often used instead of water in enemata and when concentrated possesses an irritant action on the bowel, producing peristalsis. Strong solutions are sometimes thrown into the rectum to destroy thread worms.

Isotonic salt solutions (0.6–0.9 per cent.), are often administered when the body has lost much fluid, as they are rapidly absorbed and are devoid of irritant action; thus in hæmorrhage these solutions are injected subcutaneously, intravenously, or per rectum. A rapid improvement in the circulation follows, and this has given rise to the erroneous opinion that such saline infusions stimulate the heart directly as well as by the mechanical effect of the increase in the fluids of the body; this theory has led to infusions being made in weakness of the heart from other causes than hæmorrhage. Some of the symptoms of cholera are believed to be due to the loss of fluid, and these are said to be relieved by the injection of salt solutions, though the mortality does not seem materially altered. The intravenous and subcutaneous injection of salt solution has been recommended in uræmia and similar intoxications, with the idea of washing out the poisons through the kidneys; the same results can often be obtained by drinking large quantities of water.

In the U. S. P. physiological salt solution (*Liquor Sodii Chloridi Physiologicus*) contains 0.85 per cent. of salt in freshly distilled water, and the solution must be sterilized.

The istonic salt solution ordinarily employed for hæmorrhage and other purposes is inferior to the Ringer's solution,[1] which contains the other salts of the alkalies in approximately the proportions in which they are found in the plasma; for excised organs live for many hours in this balanced solution, while they lose their vitality rapidly in an istonic solution of sodium chloride. The presence of lime salts is particularly important.

The water which is used to dissolve the salts must be recently distilled and kept aseptic; otherwise the fluid, if injected intravenously

[1] Ringer's solution suitable for mammals contains 8.5 G. NaCl, 0.3 G. KCl, 0.2 G. $NaHCO_3$, and 0.2 G. $CaCl_2$ in a liter of distilled water.

or hypodermically, is liable to cause fever symptoms from the presence of toxic substances derived from dead bacteria.

Ringer's solution or sodium chloride solution injected intravenously dilutes the blood plasma and lessens its osmotic resistance to filtration, and the whole of the injected fluid quickly passes out of the vessels into the tissues and the urine. If the object aimed at is to wash out the tissues, Ringer's solution is suitable, but if it is desired to retain the fluid in the vessels (for example, after profuse hæmorrhage), some substance which offers greater resistance to filtration must be added. Bayliss has advocated the addition to the injection fluid of 6 per cent. gum acacia, which has the effect of retaining the fluid in the vessels longer and also of giving it the same viscosity as the plasma. Clinical observations show that this new fluid possesses advantages over Ringer's solution in hæmorrhage and shock.

Ringer's solution is used in surgery to wash out the peritoneal cavity, which would be injured by distilled water.

According to a recent view, the retention of sodium chloride in the tissues may lead to the retention of fluid and may thus tend to cause œdema and dropsy. These conditions have therefore been treated by a diet containing a low proportion of salt, and in a certain number of cases with some success.

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XXXVII. POTASSIUM SALTS.

The effects of potassium in the organism can best be studied by administering the chloride, as the Cl ion is practically devoid of action and the symptoms induced by potassic chloride must therefore be due either to the "salt-action" or to the potassium. The salt-action can be discounted by comparing the symptoms with those of an isotonic solution of sodium chloride, and when this is done it is found that potassium has a distinctly poisonous action, which is chiefly manifested in the central nervous system and the heart. Some of the effects of

potassium have been said to be due to its being feebly radioactive (Zwaardemaker), and attempts have been made to substitute for it small quantities of other radioactive metals; but the connection between its action in the tissues and its radioactivity has not been established.

In the frog the central action is shown by the spontaneous movements becoming weak and slowly performed, and by their completely disappearing much earlier than in sodium chloride experiments. In mammals the chief nervous symptoms are great muscular weakness and apathy. The respiration becomes rapid and labored, probably from the anæmia of the centre. Mathison states that potassium first increases the activity of the spinal centres and then paralyzes them in mammals, but this is concealed by the depression of the heart when the drug is injected intravenously.

The depression of the heart is shown in the frog by weakness, slowness and irregularity when chloride of potassium is injected subcutaneously, but is more clearly demonstrated by the rapid failure of an excised heart when a chloride of potassium solution is perfused through it. An isotonic solution of common salt also brings the heart to standstill after a time, but potassic chloride acts much more quickly, and, in fact, the former may restore the heart beat after it has been stopped by potassium, which proves conclusively that the latter has a specific poisonous action in addition to any salt-action. Ringer, however, found that the beat of the frog's heart perfused with a solution of common salt was not so satisfactory as that of one perfused with the same solution to which some potassic salt had been added, probably because when the fluid perfused contains no potassium, some of the salts of that metal diffuse out of the muscle cells and this disturbs the ratio between the potassium and sodium which is necessary to life.

The mammalian heart is also injured by the action of potassium when the salt is injected intravenously, as is shown by weakness and dilatation, slowness of the pulse, heart block, and finally by ventricular fibrillation not infrequently; the blood-pressure falls abruptly from this action on the heart, which appears to be a direct one on the muscle, the inhibitory mechanism not being involved. The poisonous action of potassium on the heart has given rise to exaggerated apprehensions of the danger of using its salts in therapeutics, and it may therefore be noted that potassium has no effect on the heart when given by the stomach, and that very much larger quantities of potassium are taken daily in the food by thousands of persons than are ever prescribed in medicine. Bunge estimates the amount of potassium in the food of some classes at 50–100 grms. (1½ 3 oz.) per day. Meltzer has recently shown that the magnesium salts are much more poisonous than those of potassium, yet magnesium sulphate is often employed in doses of ½–1 oz. without deleterious effects. The absence of effects from the potassium ion when the salts are taken by the mouth is due to their rapid excretion in the urine. In practical therapeutics the potassium salts may be regarded as equivalent to the corresponding sodium ones except when they are injected intravenously.

The failure of the heart is the cause of death in mammals when potassium salts are injected into a vein, the respiration and the reflexes often persisting for a few seconds afterwards. When potassium salts are injected into an artery, so that they can reach the peripheral vessels before the heart, they cause marked vasoconstriction with an abrupt rise in the blood-pressure; this action appears to be a direct one on the walls of the arterioles for the most part, though it is possible that this is reinforced by stimulation of the medullary and spinal vasomotor centres (Mathison).

Potassium has some action on muscle in the frog, the contraction seeming to be somewhat greater in height, though shorter in length, and there being less tendency to contracture. Muscle exposed in a solution of potassic chloride dies much sooner than in an isotonic solution of sodium chloride. Unstriated muscle suspended in a solution of potassium chloride undergoes contraction, which may be removed by replacing the potassium with sodium.

Chloride of potassium has also some depressant action on the peripheral nerves, for they lose their irritability rapidly when they are exposed to its solutions. A concentrated solution applied to an exposed nerve causes contractions of the muscles which are supplied by it, but these are weaker and last a shorter time than those elicited by a similar solution of common salt. This is explained by the depressant action of the potassium opposing the irritation which it induces through its salt-action.

The absorption of potassium salts is followed by the same changes in the movements of the fluids of the body as have been described in the case of sodium chloride (page 515). This generally results in diuresis with an increase in the potassium and the sodium and chloride in the urine. The potassium salts are generally credited with greater diuretic properties than those of sodium. Strong solutions of potassic chloride are said to be more irritating to the stomach and also in the subcutaneous tissues, than those of sodium chloride; this would indicate that potassium has a specific irritant action apart from its salt-action, which is not unlikely, although it cannot be said to have been demonstrated satisfactorily as yet.

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Lithium, Caesium, Rubidium.

In regard to the action of the rarer alkalies, Lithium, Cæsium and Rubidium,[1] comparatively little is known. They seem to have some effect in depressing the spinal cord in the frog, but it is uncertain whether this is, like the action of sodium chloride, merely due to the presence of large quantities of salts in the body, or whether they have a specific action on the nerve cells. Lithium seems to have some further depressant action on the motor nerves, and to weaken the muscular contraction. It acts much less powerfully on the mammalian heart than potassium, but has some effect in weakening it. Its chief effects are exercised in the alimentary tract, for gastro-enteritis and

[1] The still rarer metals Yttrium, Erbium, Beryllium, Didymium and Lanthanum have scarcely received examination except at the hands of Brunton and Cash, and are not of sufficient importance to require further mention here.

extravasations of blood into the stomach and bowel are induced by its subcutaneous or intravenous injection and these are the cause of death in fatal poisoning in animals. Such violent effects are less easily elicited by the administration of lithium by the mouth, though vomiting and purging have been caused in animals by this method also, and disturbance of the alimentary tract has sometimes followed from lithium treatment in man. Some of the lithium is excreted in the bowel, and in this respect this metal appears to form a contrast to potassium and sodium and to resemble rather the group of alkaline earths. Most of it appears in the urine, however, and here the excretion is slow, for traces may be found in it for many days or even weeks after a single administration.

Rubidium seems to act on the frog's heart and on muscle cells in much the same way as potassium. It is slowly excreted by the kidneys; traces are found also in the fæces, especially if diarrhœa occurs, as is not infrequently the case.

Cæsium resembles lithium in causing inflammatory reactions in the alimentary tract, leading to vomiting and diarrhœa, when it is injected hypodermically or when large doses are given by the mouth. It is partly excreted along the alimentary tract in mammals. In the frog it induces weakness of the muscles and paralysis.

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XXXVIII. AMMONIUM.

Although ammonium is not a metal, its behavior in the body resembles in many points that of the fixed alkalies, and it may therefore best be studied along with them. The solutions of ammonia and the gas itself are strongly alkaline and therefore powerful irritants, and the general action of the ammonium ion can be determined only by the examination of those of its salts in which, as in ammonium chloride, the effects of the anion can be neglected. The action of chloride of ammonium is due to the specific action of the base and to the salt-action.

Action.—Its most striking effect is the stimulation of the **Central Nervous System,** which is induced when it is injected subcutaneously or intravenously. The reflex irritability is much increased, and this may be followed by tetanic convulsions, both in frogs and mammals. These convulsions persist after division of the cervical spinal cord and destruction of the medulla oblongata and brain, and are evidently caused by changes in the spinal cord, similar to those met with in strychnine poisoning. The medullary centres are also involved, for the respiration very often ceases for a moment, and then becomes much accelerated, and in some instances deeper, from stimulation of the centre.

The blood-pressure rises from contraction of the peripheral arterioles, induced by stimulation of the vasomotor centre, while the heart is sometimes slowed from increased activity of the inhibitory centre,

but is said to be accelerated in other cases; whether this arises from action on the cardiac muscle or on the accelerator centre is still unknown.

During the convulsions the respiration is arrested and the blood-pressure becomes extremely high. If large enough quantities be injected, the stimulation is followed by paralysis of the central nervous system and the animal dies of asphyxia, but if artificial respiration be carried on, it recovers rapidly, from the salt being eliminated.

In the frog ammonium chloride tends to paralyze the terminations of the **Motor Nerves**, but little or no such action is met with in mammals. This marked curara-like action differentiates the ammonium tetanus of the frog from that seen under strychnine, as the spasms last a shorter time, and soon become weaker, from the impulses failing to reach the muscles through the depressed terminations. The **Muscles** themselves are also acted on by ammonium in much the same way as by potassium. Ammonium chloride is credited with rendering the mucus secretion of the stomach and bronchi more abundant and less tenacious, but there seems no foundation for this belief.

Ammonium salts penetrate most cells of the body more freely than the salts of the fixed alkalies, and solutions of ammonium chloride are therefore **absorbed** more rapidly from the stomach and intestine than those of sodium or potassium chloride. They permeate into the blood cells with still greater freedom, and, in fact, solutions of the chloride of ammonium meet with little more resistance in entering the red-blood corpuscles than does distilled water. If ammonium be combined with a non-permeating ion it penetrates the blood cells or the intestinal epithelium with difficulty, however, so that the sulphate of ammonium is slightly cathartic, although less so than the sulphates of the fixed alkalies. (See Saline Cathartics.) The epithelium of the lungs has been stated to be impermeable by the ammonium ion, but this appears to be incorrect (McGuigan).

When ammonium salts are taken by the mouth, they have little or no tendency to cause symptoms from either the central nervous system or the heart. No case is known in which convulsive attacks could be shown to be due to the direct action on the central nervous system in man, and it is very doubtful whether the circulation is affected at all. In some cases of poisoning with ammonium hydrate, convulsions have occurred, but these seem to be due to the violent irritation caused by the strong alkali.

Excretion.—Some ammonium is excreted unchanged in the urine, while some is changed to urea. This transformation, which probably takes place in the liver chiefly, proceeds very rapidly, so that considerable quantities may be injected slowly into a vein without inducing any symptoms whatever. This formation of urea occurs more readily in the herbivora than in man and the carnivora, and is especially seen when the ammonium is given in the form of the carbonate or of salts which are oxidized to the carbonate in the body, such as the acetate and citrate; in the herbivora the abundant fixed alkali of the blood and tissues displaces

the ammonium of such salts as the chloride, and the carbonate of ammonium thus formed is changed to urea, while in the carnivora and man, the supply of fixed alkali is less abundant and the ammonium chloride is not changed to the same extent. The administration of ammonium chloride is therefore followed by an increased elimination in the urine of urea and of the chlorides of sodium and potassium which are formed by the interchange, especially in the herbivora; at the same time the fixed alkalies of the blood are reduced in amount, and this may give rise to symptoms of acidosis (see Acids).

The urine is often increased by the exhibition of ammonium salts, but not always. It is to be noted that, while the alkaline salts of the fixed alkalies render the urine less acid or even alkaline, ammonium salts have no such effect, because they are excreted as urea or as neutral salts.

In birds and reptiles ammonia is apparently excreted as uric acid.

The **Substituted Ammonias** of the methane series, such as methylamine, and some of those of the aromatic series resemble ammonium in their general effects, but the stimulation of the central nervous system is not often so marked. In general terms, those compounds in which one hydrogen atom is substituted, tend to cause greater nervous stimulation than those in which two or three such substitutions are made, while this action is again more prominent in those in which four alkyl groups are combined with the nitrogen. In addition, most of these compounds seem to have a more depressant action on the central nervous system afterward than ammonium, and they all tend to weaken and eventually to paralyze the terminations of the motor nerves. Some of them slow the heart by an action resembling that of muscarine, while others act on the peripheral ganglia like nicotine.

The ammonium bases formed from the natural alkaloids appear to have less action on the central nervous system, but act like curara on the terminations of the motor nerves.

Preparations.

Ammonii Chloridum (U. S. P., B. P.) (NH_4Cl), 0.3 G. (5 grs.); B. P., 5–20 grs., in solution.

Trochisci Ammonii Chloridi (U. S. P.), each containing 0.1 G. (2 grs.) of ammonium chloride with 0.2 G. (4 grs.) of liquorice extract and some syrup of Tolu.

Therapeutic Uses.—The chloride is prescribed chiefly for its effects on the respiratory mucous membranes, and is a very common constituent of expectorant mixtures for bronchitis and catarrh. The lozenge is often used for sore throat, and chloride of ammonium solutions are occasionally inhaled or sprayed into the throat. It has also been prescribed in gastric catarrh with benefit in some cases, but whether this is due to its acting on the mucous secretion is unknown.

The other ammonium salts are used only for the effects of the anions and will be discussed in connection with these.

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XXXIX. IODIDES.

Although the iodides have been more largely used in medicine than any of the other salts of the alkalies, their mode of action is still wrapped in obscurity. The attention of investigators has been drawn to the symptoms of poisoning rather than to the therapeutic action, and the effects seems to vary considerably not only in different individuals, but also in the same person at different times.

Symptoms.—Large quantities of the iodides cause irritation of the stomach from their salt-action and induce nausea and vomiting, more rarely diarrhœa; but these symptoms are quite distinct from those known as **Iodism,** which may arise from comparatively small quantities, and which are most commonly seen when the remedy has been administered repeatedly.

The commonest symptom of iodism is catarrh of the **Respiratory Passages,** more especially of the nose, which betrays itself in some swelling and discomfort in the nasal mucous membrane, in a profuse watery secretion, and in sneezing. The catarrh spreads upward to the conjunctiva, which often becomes swollen and congested, and to the frontal sinuses, where it induces a feeling of dulness or violent headache; it also progresses downward to the tonsils, which become swollen and inflamed in some cases. Still lower it occasionally causes some swelling and œdema or small ulcers in the larynx, and has thus caused dyspnœa, which has necessitated tracheotomy, or very rarely has proved fatal. Bronchitis has also been observed in man, with a profuse watery secretion, and in animals œdema of the lungs and pleuritic effusion have been produced by the injection of iodides. Even small quantities injected intravenously increase the mucus secreted by the bronchi.

In the **Mouth** iodism is often betrayed by swelling and irritation of the throat and tonsils and by salivation, rarely by swelling of the salivary glands. The stomach is seldom affected, the appetite generally remaining good, but in some persons iodides induce nausea and gastric discomfort. A single dose of iodide increases the amount of gastric juice and prolongs the secretion aroused by the taste of food.

Skin Eruptions of different forms are also common results of the administration of iodides, but are less liable to occur in the beginning of the treatment than the catarrh of the respiratory passages. These eruptions may simulate almost all known skin diseases, but the most common forms are erythematous patches, or papular eruptions, which

may pass into pustules or into larger inflamed areas. Eczema, bullæ, pemphigus and purpura arise less frequently from the use of iodides. In some cases a more or less defined area of œdema has been observed in the face.

The **Secretion of Urine** is generally increased by the administration of iodides, as of other salts of the alkalies, though they seem to have no specific action on the kidneys. In rare cases albuminuria has been observed, and some irritation of the bladder, urethra and vagina is said to have been induced by iodide treatment, but these statements require confirmation.

In abnormal conditions of the thyroid gland, the iodides and many other iodine compounds often give rise to a series of symptoms which are due to the excessive production of the specific secretion of the gland, which itself contains iodine; these symptoms are quite distinct from those described as iodism and may rather be referred to as thyroidism. Among these symptoms are acceleration and palpitation of the heart, tremors, nervousness, sleeplessness and disorders of sensation, such as localized anæsthesia or neuralgic pains. Sometimes some fever or accelerated metabolism leading to loss of weight has occurred, and occasionally extreme emaciation and cachexia with mental depression, which only abated slowly on the abandonment of the treatment, or which in rare cases were permanent.

In many instances small doses of iodide may be given repeatedly without any noticeable disturbance, but in others the smallest quantity (0.2 G.) induces severe poisoning. Some authorities consider that these small doses are more liable to cause iodism than larger ones, but this may be doubted, as the action of the drug is so capricious that the statistics of different observers show great discrepancies, even when approximately the same dose has been given. Thus, Haslund, treating patients with at first 3 G. (45 grs.) and then 5 G. (80 grs.) daily, observed iodism in only 12 per cent. of his cases during the first few days, while others have found iodism induced in 60 per cent. of their cases after a single dose of 3 G. An attempt has been made to explain these discrepancies by supposing that iodism is only produced by impure iodides, but this is not correct, for it has been observed in numerous cases in which the drug was absolutely pure. Among other conditions which favor the onset of symptoms is a slow excretion of the iodide such as is observed in some forms of renal irritation. Children seem less liable to suffer from the iodides than adults. The dose administered has, of course, some relation to the onset of symptoms; thus, very large doses are more likely to induce them than very small ones, but it seems that a tolerance is soon established in some cases, for after iodism has been induced, and the daily dose lessened accordingly, it is sometimes found that it may be gradually increased until a quantity considerably greater than that originally given may be taken with impunity. In other instances, a definite quantity may be given for a long time without inducing symptoms, but these may suddenly set in without any apparent change in the treatment and

without any appreciable cause. Very often it is found that the symptoms disappear while the treatment is continued, and recovery invariably sets in when the drug is abandoned. The iodides all induce iodism, the symptoms being apparently unaffected by the basic ion. The condition is seldom dangerous, but a few cases are recorded in which œdema of the larynx resulted and proved fatal.

The iodides are not **Absorbed** from watery solutions applied to the skin, but are rapidly taken up by all the mucous membranes. When given by the mouth they are absorbed unchanged by the intestine, and appear in the secretions within five to ten minutes. The greater part of the iodide is **Excreted** in the urine, in which it appears as salts. Some escapes by the salivary glands, however, and small quantities are excreted by the stomach as hydriodic acid, from which free iodine may be formed; iodide has also been found in the tears, perspiration, milk, sebum, and in the secretion of the nasal mucous membranes. More iodide is found in the blood than in any of the fixed tissues; the skin is also rich in iodide, while the lungs, kidneys and lymph glands contain smaller quantities; the brain and fatty tissues have merely traces; necrotic tissues take up more than sound ones because the dying cells no longer oppose resistance to the diffusion of the salts.

Iodides are much more rapidly excreted than bromides, for 65–80 per cent. of the iodide appears in the urine within twenty-four hours after its administration, and no iodide reaction is obtained from any of the secretions a week after the treatment has ceased. Some of the iodide does not appear in the urine, however, and its fate in the body has not been very clearly traced. Different individuals vary in the amount that thus disappears, which seems to be fairly constant for each person; thus one patient receiving 0.5 G. of potassium iodide may retain 0.1 G., while another after the same dose may retain 0.2 G. or more, the same proportions appearing on different occasions.

The greater part of the iodide administered therefore passes through the tissues and is excreted in the urine in the form of salts. Some of the iodide undergoes decomposition in the body, however, for free iodine has been found in the stomach, and an organic compound of iodine exists in the hair and in various internal organs after iodide treatment. The successful treatment of goitre with iodide of potassium is also a strong argument in favor of the presence of free iodine, and the iodine of the thyroid glands has been shown to be increased by potassic iodide. When iodine is thus liberated in the body, it does not circulate as such, but at once combines with the proteins, and its presence can no longer be demonstrated by the ordinary tests.

The formation of free iodine from iodides (which is, of course, quite distinct from their dissociation into potassium and iodide ions) has been the subject of several ingenious theories, none of which have been established and which are now chiefly of historical interest and need not be entered on here.

It is often said to be set free along the mucous membrane of the respiratory passages and in the skin; and in this way the coryza of the former, and the eruptions on the latter are explained. It must be noted that free iodine has not yet been clearly demonstrated on either of these surfaces, and that the

theory has been formulated only to explain the symptoms of iodism. Iodides have been found in the nasal secretion, saliva and perspiration, but no free iodine.

The central nervous system and the circulation scarcely seem to be affected by iodides. Very large quantities of potassic iodide injected into a vein are found to weaken and paralyze the heart in animals, but do not seem to be more poisonous than other potassium salts, and depression of the central nervous system may also be elicited in the same way by the potassium action. Barbera states that very large quantities of iodides paralyze the depressor nerve terminations in the medulla oblongata and weaken the peripheral inhibitory mechanism of the heart, while Hunt found the accelerator fibres less easily fatigued after iodide. The metabolism of the body seems little affected by iodides in most cases, but a further examination of the excretions of patients who lose weight under the treatment is desirable. Fatty degeneration of the liver is stated to occur in some animals. The action of the iodides in therapeutics has been ascribed by some authors to their rendering the movement of the leucocytes (diapedesis) more active, but no satisfactory evidence has been adduced in support of this. Solutions of iodide of sodium are found to be more poisonous to muscle, cilia and unicellular organisms exposed to them than are similar solutions of the chloride or bromide, so that the iodide ion appears to be more fatal to protoplasm than the bromide and chloride ion, while it is less poisonous than the fluoride. In the frog stiffness and awkwardness in the movements are elicited by comparatively small doses of iodide of sodium and these symptoms have been shown to be due to rigor mortis occurring in the muscles.

The rapid elimination of iodide by the kidney necessitates frequent large doses if the action is to be maintained, and these large doses in turn tend to induce iodism. An attempt has therefore been made to introduce iodine combinations which are slowly decomposed in the tissues and thus free iodide continuously. For this purpose protein compounds with iodine (*Eigon*, *Iodolen*, etc.), have not proved successful, as they tend to free the iodine in the alimentary tract and the resulting iodide is eliminated almost as quickly as when inorganic iodide is administered. Combinations of iodine with oil (*Iodipin*) or with fatty acids (*Sajodin*) are absorbed, stored in the fat depots of the body and gradually decomposed with the liberation of iodides. No iodine is found in the urine in the first hour after the administration of these organic compounds and the maximum excretion takes place after ten hours; the iodide reaction disappears from the urine after eighty-four hours. The amount of iodide formed from the decomposition of sajodin is insufficient to exercise any therapeutic action.

Preparations.

Potassii Iodidum (U. S. P., B. P.) (KI), 0.3 G. (5 grs.); B. P., 5–20 grs
Sodii Iodidum (U. S. P., B. P.) (NaI), 0.3 G. (5 grs.); B. P., 5–20 grs.

The iodides form colorless crystals when pure, a yellowish tint indicating the presence of free iodine. They are very soluble in water, less so in alcohol, and are always prescribed in watery solutions, and often along with carbonate of sodium or potassium, in order to prevent decomposition as far as possible. The iodide of potassium is the one most frequently used and is less liable to contain free iodine than the others, but iodide of sodium is preferred by some; the dose often has to be much increased beyond that given above. The iodide of ammonium is said to be more liable to cause skin eruptions and disturbance of the digestion than the others. Some iodide effects may also be obtained by the use of iodide of lead or mercury, but here they are complicated by the action of the metal, and these will be discussed along with the other salts of lead and mercury. The external application of iodides is not attended by any general effect, though some irritation may be induced by iodine being liberated by the decomposition of the fats; small quantities of iodine are absorbed and changed to iodides in the tissues.

Iodipin (unofficial) is an iodine addition product of sesame oil and forms a yellow oily liquid with an oily taste. It is prepared in two strengths containing 10 per cent. and 25 per cent. of iodine, respectively. Dose 4–8 mils (1–2 drs.) of iodipin 10 per cent. Hypodermically 2–6 mils (30–90 mins.) of iodipin 25 per cent.

Sajodin (unofficial), $(C_{21}H_{42}ICOO)_2Ca$, the monoiodobehenate of calcium, is a colorless and tasteless powder insoluble in water. Dose, 1–3 G. (15–45 grs.) daily.

Therapeutic Uses.—The iodides are used very extensively in the treatment of tertiary syphilis, in which they have proved invaluable. They have also been administered in the earlier stages of the disease, but have proved to be of little service here. In syphilitic bone disease and ulcers, and in the gummata of the brain and other internal organs, however, a remarkable improvement very often occurs after the iodide treatment has been adopted. The iodide of potassium or of sodium is almost invariably used, and is given in as large doses as the patient can bear, often up to 5 G. (75 grs.) daily. The iodide is often prescribed along with mercury, and this combination is found more efficient than the iodide alone. In actinomycosis iodide treatment has proved of value, and in a rare infection known as sporotrichosis, which arises from a fungus nearly related to actinomyces, Bloch states that the effects are even more striking than in tertiary syphilis.

In syphilis and in these other diseases, the iodide does not act as a parasiticide; the spirochæta of syphilis, for example, is not killed by the application of iodide of potassium to a syphilitic lesion, and the fungus of sporotrichosis grows readily in a culture medium containing high concentrations of iodide. The specific effects of iodide in tertiary syphilis are exerted not on the parasite but upon the tissues in which it lives and which have reacted to its presence by the formation of tumors; these lowly organized tumors dissolve under the action of iodides, while the parasite remains unaffected, but is now more readily accessible to the parasiticide drugs, mercury and arsenic. It is important to recognize that iodide does not destroy the cause of the infection but only removes some of the results.

It is unknown how iodide removes the gummatous tissue; it accumulates in poorly nourished, necrotic tissues in greater concentration than elsewhere, because these have lost their power of resisting the permeation of salts which therefore diffuse into the cells freely. This is not specific for syphilis, and probably other salts would also be found in higher concentration in these tissues than in others. Kepinow found that iodide injected intravenously in animals accelerates the autolysis of the liver, and an analogous observation has been made by Jobling and Petersen, who found that serum no longer inhibits the trypsin action in the presence of iodides, and that in patients treated with iodide the antitryptic action of the serum is lowered; it is possible that it similarly promotes the autolytic solution of the gumma by removing the antagonistic substances.

In many diseases which are not directly attributed to syphilis,

but in which there is a history of syphilis, iodides are of value; thus, neuralgia and other nervous disturbances are often relieved by them in persons of a syphilitic taint, and in fact, improvement is often observed in the most diverse conditions in persons who have formerly suffered from this complaint.

Another series of symptoms, or of diseases, which is often treated with iodides is rheumatism in its various manifestations. The treatment is of little value in acute rheumatism, and in fact, often fails in the chronic disease, but is occasionally attended with improvement, although the exact conditions in which this occurs are still unknown.

The iodides have long enjoyed some reputation in the treatment of goitre, but the thyroid extract has proved much superior to them and promises to supplant them entirely, as their effects are due to their action on the thyroid secretion. The same may be said regarding their use in obesity, which was found to be successful in some cases, presumably of thyroid insufficiency. When thyroid insufficiency is due to the absence of iodine, while the gland cells are capable of normal action, iodides and iodine give good results; but when the symptoms arise from absence or atrophy of the secretory cells, iodides are valueless, and relief is given only by the administration of the specific secretion. The increase in the iodine of the thyroid gland under iodide treatment has been studied by Marine and his associates, who point out that the iodine is first taken up by the gland in an inactive form and is then slowly changed into the physiologically active combination. In some districts in which goitre is prevalent, good results have been obtained by giving iodide as a preventive measure; the children are given ten doses of 0.2 G. each during ten days twice a year.

Some skin eruptions have been found to be benefited by the iodide treatment even when no suspicion of syphilis could be entertained.

The success attending the treatment of goitre with iodides seems to have been the basis of their use in cases of enlarged lymphatic glands, scrofula, and lupus, but here the results are very doubtful, although some authorities allege that the iodide treatment is of value. There is a general consensus of opinion that the old treatment of malignant tumors, such as cancer and sarcoma, with iodides is hopeless.

These salts are sometimes credited with promoting the absorption of serous effusions, and the removal of hypertrophy of connective tissue in the body, as in the various forms of sclerosis and cirrhosis. Their efficacy in removing the syphilitic gumma was evidently the origin of their use here, but while the resolution of gummata under the iodides is beyond question, no satisfactory evidence of improvement in these non-syphilitic affections is available.

Aneurism and arteriosclerosis have often been treated with iodide, and improvement is undoubtedly observed in some cases, in which there is probably a syphilitic taint; but there seems no reason to suppose that the iodides have any special action on the vessels apart from their action on poorly organized tissue, such as is formed in syphilitic

infection, for no change in the heart, pulse or blood-pressure can be observed even after prolonged treatment.[1]

Iodides are often prescribed along with other remedies in expectorant mixtures, the object being to render the bronchial mucus more watery and less tenacious, and thus to facilitate its removal. In some cases of asthma they have been found of value, perhaps from the same action, for they do not appear to affect the bronchial muscle.

Iodide of potassium is generally prescribed in chronic poisoning from lead or mercury, and is believed to hasten the elimination of these metals, although it has not been shown that it is of more value here than other salts, such as the chlorides and bromides. The belief in the efficacy of the iodides in mercury poisoning has suggested that they act in tertiary syphilis only by aiding in the mobilization of the mercury stored in the tissues from the treatment of the earlier stages, but this is incorrect, for the iodides are of value in cases of tertiary syphilis in which mercury has not been previously used. It is stated that when iodide is given along with mercury, the latter does not accumulate in the liver, but the statement requires confirmation.

Finally, iodide of potassium is sometimes added to other drugs in cases of malingering, or in which it is suspected that the patient is not taking the remedy as directed. If the iodide is swallowed it can be detected in the urine by the addition of a few drops of chlorine water and of starch solution, which assumes the well-known blue color.

Iodides have to be used with care in cases of pulmonary phthisis, in which they often increase the cough and expectoration, and in some cases, it is alleged, cause hæmoptysis and promote the infection of fresh tissue. If the tubercular nodule is broken down by the iodides in the same way as the gumma, the bacillus may be freed, and many clinicians deprecate the use of iodide in all forms of tuberculosis. Children have sometimes been found to suffer from iodism from being nursed by a person under iodide treatment.

Iodism very often proves a disagreeable accompaniment of the treatment, and is sometimes so severe as to preclude the use of the salts, so that many attempts have been made to discover some expedient by which these symptoms may be avoided, but as yet no success has been obtained. Iodism occurs less readily under the organic preparations iodipin and sajodin, but it is not yet satisfactorily established that the specific action in syphilis is induced as certainly by these as by the inorganic iodides; in grave cases the latter should certainly be employed in preference.

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[1] The supposed action in arteriosclerosis has sometimes been ascribed to iodides lessening the viscosity of the blood; but the experiments on which this explanation is based are not convincing

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XL. IODINE.

Iodine possesses a local irritant action similar to, though less intense than, that of chlorine and bromine (p. 171). It is much less volatile, and therefore comes into contact with the tissues more slowly than these, but the chemical change is analogous, and iodides and iodo-protein compounds result.

Action.—When applied to the **Skin**, it dyes it a yellow-brown or dark brown color, and acts as an irritant, producing a sensation of heat and itching. In very concentrated solution or in the solid form it may cause blistering or even corrosion, but it acts more slowly than most other irritants, and at the same time the irritation is more prolonged. It penetrates into the deeper layers of the skin, and small quantities are absorbed.

The **Mucous Membranes** are more strongly affected by contact with it; thus when its vapor is inhaled for some time, smarting, swelling and increased secretion is caused in the nasal mucous membranes, conjunctiva, throat and lower respiratory passages, resembling exactly the symptoms known as iodism. In the stomach small quantities may cause slight irritation and improved appetite, but as a general rule nausea, discomfort and vomiting follow its administration in any save the most minute doses, and occasionally diarrhœa has been observed after it from irritation of the bowel. In cases of poisoning, the irritation of the alimentary canal may prove fatal by inducing collapse and failure of the heart and respiration, and iodine may be recognized in the vomited matter and in the stools.

Solutions of iodine **Injected Subcutaneously** or into tumors or cysts, a common method of treatment formerly, cause intense pain and irritation, which may induce collapse and which have been followed in some instances by suppuration and gangrene.

Iodine is **Absorbed** in the form of iodides, and perhaps in combination with proteins. Its fate in the body is precisely similar to that of the iodides—it is excreted in the form of iodides, chiefly by the kidneys, to a less extent in the saliva, perspiration, milk and secretions of the respiratory passages. The administration of iodine leads to an increase in the iodine of the thyroid gland.

Small quantities of iodine may be given internally to many persons without eliciting any symptoms except those which are clearly due to the local action. Repeated doses, however, sometimes cause symptoms resembling those observed after iodides (**Iodism**), although these have been much less often induced by iodine, which is comparatively seldom administered internally. Many other symptoms which have been observed under iodine treatment, obviously arise from the excessive activity of the thyroid gland, and are especially noticeable in goitre.

Some **Cases of Poisoning** from the injection of large quantities of iodine into cysts have been recorded. In Rose's well-known case, the chief symptoms were thirst, constant vomiting (the vomited matter containing iodine) cyanosis and coldness of the skin, a small, weak pulse, anuria and skin eruptions after a few days; and death occurred on the tenth day. In such cases of poisoning in man the mucous membrane of the stomach and intestine has been found swollen and loosened, and in animals fatty degeneration of the liver, heart, and kidney has been described.

Injected into the veins of animals, iodine causes œdema of the lungs, which v. Zeissl considers to be due in part to changes in the left ventricle, in part to contraction of the pulmonary arterioles.

Preparations.

Iodum (U. S. P., B. P.), iodine, is not used in therapeutics.

Tinctura Iodi (U. S. P.), 7 per cent., 0.1 mil (1½ mins.).

Liquor Iodi Compositus (U. S. P.), Lugol's Solution, contains 5 per cent. dissolved in 10 per cent. potassium iodide solution. 0.2 mil (3 mins.).

Unguentum Iodi (U. S. P., B. P.), 4 per cent.

Tinctura Iodi Fortis (B. P.), Iodine Liniment, about 10 per cent. of iodine dissolved in alcohol with potassium iodide.

Tincture Iodi Mitis (B. P.), 2½ per cent., 2–5 mins.

Therapeutic Uses.—Iodine has been used internally in a variety of chronic conditions, such as syphilis and goitre, and in tubercular disease of the glands, bones and other organs, but it has been almost entirely superseded by the iodides, and in goitre by the thyroid preparations.

It has been applied locally by painting on the skin in a variety of chronic inflammatory processes, such as tubercular glands, pleuritic effusion, and tubercular or rheumatic joint disease. Its action here consists simply of a mild lasting irritation of the skin, which induces some congestion in the subcutaneous tissues and may thus aid in the absorption of exudates in them and may also influence the deeper lying tissues and organs in the same way as other irritants (see page 75). There is, however, nothing specific in its action, and it differs from the other skin irritants only in being milder in action and more enduring in its effects. It seems unlikely that the small quantity absorbed can have any appreciable action. Some benefit often follows from this use of iodine in chronic inflammations, but there is no question that it is very often applied where more active surgical measures are really required.

Iodine was formerly injected into cysts in order to induce inflammation and adhesion of their walls, and thus to obliterate the cavity. It has recently been used extensively to disinfect the skin before operation (see page 153).

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See Iodides, Thyroid Extract.
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XLI. THYROID GLAND.

The treatment of certain diseases by the administration of thyroid gland and its extracts is one of the most satisfactory examples of rational therapeutic progress, and the steps which led to its adoption may therefore be briefly mentioned. In 1882–3, Kocher and Reverdin published observations made on patients whose thyroids had been totally extirpated, and who had subsequently presented a series of symptoms to which these observers gave the name of cachexia thyreopriva. They pointed out that this condition resembled in many of its features myxœdema, a disease discovered by Gull some years before and associated with atrophy of the thyroid gland. These observations were confirmed by a number of authors, who removed the thyroids from animals, and found a cachexia appear in them. The next advance was the discovery that these symptoms in animals could be removed, or at any rate ameliorated, by grafting pieces of thyroid in the peritoneal cavity or subcutaneous tissue. Horsley suggested that myxœdema should be treated in the same way, and Murray soon afterward introduced the treatment of this disease by the subcutaneous injection of thyroid juice. Even in his first case, the results were eminently satisfactory, but it was soon found that the same results could be obtained by administration by the stomach, and a large number of cases have now been recorded in which very favorable results, or even the complete disappearance of the symptoms has followed this medication. These include not only myxœdematous patients, but also cases in which the thyroid was removed by surgical operation, or where its disease gave rise to symptoms. That the favorable results are due to the treatment is proved conclusively by the return of the symptoms when it is abandoned.

The effect of the thyroid treatment could be explained only by the presence of some chemical principle, for the preparation of course contained no living cells. A globulin, *thyreoglobulin*, was extracted from the gland, which had the therapeutic action and gave the ordinary protein reactions but was characterized by containing a small percentage of iodine; Baumann's detection of this element in the thyroid gland was the first intimation that it existed in the tissues of the higher animals and man. From this protein combination, Kendall has recently split off *thyroxin* ($C_{11}H_{10}O_3NI_3$), which is an indol derivative containing 65 per cent. of

iodine and is nearly related to the amino-acid, tryptophane. Thyroxin is a white crystalline substance, which possesses the characteristic action of the gland, in which it exists in protein combination; it is believed, however, that it is secreted into the blood and carried to the tissues in the free state; it can be obtained in several slightly different forms according to the solvent employed. The whole specific action of the thyroid preparations is due to the presence of thyroxin, and their value may thus be determined by estimating the amount of iodine they contain. This content of iodine, and of thyroxin, varies greatly in different glands according to the supply of iodine in the food, and is much increased by treatment with iodides or iodine or its compounds. Thyroid preparations are used to replace the normal secretion when it is absent or deficient from any cause, and thyroxin may be used for the same purpose and with equal success.

Action.—The thyroid preparations and thyroxin often have little obvious effect in normal persons or animals unless given in what would be large doses for others; symptoms develop slowly and the maximum effect of a dose may not be reached for several days. Undesirable effects are more liable to be induced by repeated doses than by a single large one. These symptoms are partly subjective and indefinite, such as headache, wandering pains, or general weakness, while others indicate circulatory changes, and consist of a feeling of fullness and congestion of the head, palpitation of the heart, and acceleration, sometimes weakness, of the pulse. Tremors in the arms and legs point to changes in the central nervous system, while loss of appetite and diarrhœa indicate that the alimentary canal is not exempt from its influence. Perspiration is often complained of, especially in myxœdema, and a rise of temperature also occurs not infrequently. The most striking effect in the majority of cases is a rapid loss of weight.

In normal animals thyroid extract injected intravenously in large quantities is said to accelerate the heart and lower the blood-pressure sometimes, and when given by the mouth repeatedly for several days, it may also cause some acceleration. This quickening of the heart has been attributed by some investigators to stimulation of the accelerator centre, by others to direct action on the heart; it does not seem to be due to any changes in the inhibitory apparatus and is not by any means an invariable result of thyroid treatment. In some instances in which it is induced in animals by prolonged treatment with large doses, it may arise from the metabolic changes.

Loss of flesh and thirst have been observed, even when the appetite is good and sufficient food and water are supplied. The urine is uniformly increased in amount. A number of observers have found that the continued administration to animals of thyroid preparations in large amounts leads to diarrhœa, muscular weakness, especially in the hind extremities, emaciation, gastro-enteritis, nephritis, and fatty degeneration of various organs. In other instances no such symptoms have been elicited, the animals remaining perfectly normal after prolonged treatment. Different species of animals vary greatly in their

susceptibility to thyroid treatment, and this may explain some of the anomalous results recorded. In other instances, the absence of symptoms may have been due to the extract having been prepared from thyroids containing little iodine.

The **Metabolism** is changed by thyroid medication more uniformly than any other function, and this is its essential effect. All the nutritive processes seem to be accelerated. This may be observed in many individuals in the rapid loss of weight, which often amounts to several pounds per week. Again, the amount of nitrogen in the urine is increased both in goitre and myxœdema, and very often in apparently normal persons. More nitrogen is excreted in the urine frequently than is taken in the food, that is to say, the treatment leads to the destruction of the proteins of the tissues. If more nitrogenous food be given, however, this may be arrested, and in fact if large quantities of meat be taken, less nitrogen may be excreted than is taken in the food, so that although the patient is losing in weight, he may be actually increasing in nitrogenous tissue. The increase in the nitrogenous excretion is not stayed by the administration of carbohydrates and fats on the other hand, because the glycogenic function of the liver is disorganized by thyroid treatment. The increase in the nitrogen of the urine is accounted for almost entirely by the increase in the urea; the ammonia shows a very slight rise, while the uric acid and the creatinin remain almost unchanged; some creatin appears in the urine.

The other constituents of the tissues also are consumed more rapidly, and in fact the accelerated protein waste only accounts for about one-sixth of the loss in weight. The fats are reduced throughout the body, and the sugar metabolism undergoes modifications, which are shown in the disappearance of glycogen from the liver (Cramer and Krause) and not infrequently by the occurrence of glycosuria, either spontaneously or after the ingestion of quantities of sugar which would be oxidized completely in normal persons.

The acceleration of the metabolism is also shown by the increased amount of oxygen absorbed and of carbonic acid exhaled under thyroid treatment. This has been noted in myxœdema, goitre and obesity treated with thyroid, and has recently been shown to be the most regular effect of thyroxin; 1 mg. is sufficient to increase the basal metabolism by 2–3 per cent., while regular treatment with 2 mgs. per day may raise it 20–30 per cent.

The removal of fluid from the body, perhaps the most potent factor in reducing the weight in these cases, is shown by diuresis, which occurs in myxœdema especially, but also in obesity. This diuresis has been ascribed to some specific action on the kidney, or to the changes in the circulation, but may perhaps be due to the increased excretion of urea and other urinary substances. That the kidney is acted on in some cases is shown by the occasional appearance of albumin in the urine of patients treated with thyroid preparations. The phosphates excreted are increased in the same ratio as the nitrogen, and the increase is obviously due to the same cause, augmented protein waste.

It is believed that about 0.5–1 mg. of thyroxin undergoes destruction in the body normally each day and it has been calculated that on an average the normal human body contains 15 mgs.; this amount of thyroxin given to a thyroidless patient will continue to act for one or two months, after which the previous condition recurs.

Kendall states that when injected into the blood about 40 per cent. is excreted in the bile and 13 per cent. in the urine within two days; there is thus little response to a single dose, but if the same total amount is given in repeated small doses, marked effects may be elicited. After thyroid preparations have been administered, iodine is found in the urine in the form of iodides, so that the thyroxin is evidently decomposed, at any rate in part, in the body.

The absence or atrophy of the thyroid gland in young animals or children arrests the growth both physical and mental, and treatment with thyroid extract accelerates the growth in many of these cases. In normal growing mammals, treatment with thyroid does not alter the general increase in size and weight much, but some organs, such as the heart, liver, suprarenals, kidney and pancreas grow more rapidly. In tadpoles fed with thyroid the increase in size is slowed or arrested, but the metamorphosis is much accelerated (Gudernatch), so that there results a number of small frogs, while the untreated controls are still large tadpoles; this accelerated development has been used to estimate the quantity of active principle in preparations of the gland. In other amphibia in which the metamorphosis is slower and less regular than in tadpoles, the results of thyroid treatment are even more striking.

In regard to their reaction to thyroid medication, individuals vary considerably, for many are scarcely affected by it in any way, and this is particularly true of children, while others lose weight rapidly, and under larger doses show symptoms of poisoning (thyroidism). These seem to be more easily elicited in goitre and myxœdema than in ordinary cases.

The fact that "thyroidism" occurs more frequently in myxœdematous than in normal persons seems difficult of explanation, and it has been suggested that the symptoms are due, not to the extract itself, but to the products of its action. It may be supposed that in myxœdema a large amount of some substance accumulates in the tissues, because the secretion is not present in sufficient quantity to decompose it, and that when the thyroid treatment is commenced, the body is flooded with the products of decomposition and these give rise to symptoms. In normal persons, on the other hand, there is no such accumulation, and the extract therefore induces no symptoms until it is given in such quantity as to induce intoxication itself. For some years the view has prevailed that exophthalmic goitre, or Graves' (Basedow's) disease, arises from an excess of the specific secretion of the gland being poured into the general circulation, and a good deal of ingenuity has been employed in showing that the symptoms of Graves' disease may be induced by the administration of thyroid extracts. Unbiassed examination indicates, however, that thyroidism is only one symptom of an unknown underlying anomaly present in Graves' disease, and that the hyperthyroidism induced by thyroid treatment is not accompanied by the other characteristic features of exophthalmic goitre.

Iodine, as has been stated, increases the iodine of the gland, and this explains the beneficial effects formerly seen in goitre from the application of iodine internally and locally. When iodine was efficient in those cases, and any considerable diminution of the gland occurred, it was often accompanied by symptoms exactly resembling those produced by large doses of the extract. Those

symptoms were caused by small quantities in some patients, while much larger doses had no such effect in others—a fact which gave rise to some discussion and several erroneous theories. Sometimes the acute symptoms passed into a cachexia of very long standing. The quantity of iodine required to act in goitre is much greater than the iodine of the thyroxin necessary, and this shows that the latter acts not merely as an iodine compound, but as the specific substance of the gland. If the thyroid gland tissue is intact and capable of functioning, iodine or iodides are useful in these cases of thyroid inefficiency because they lead to the formation of thyroxin. But when the secretory cells of the gland are entirely destroyed, iodine cannot give relief because no thyroxin can be formed; here the specific secretion—thyroxin—itself must be supplied. Various iodine compounds, such as *iodalbumin* and *iodospongin* (the iodine compound of the sponge) have been shown to be practically inert in goitre.

Preparations.

Thyroideum Siccum (B. P., U. S. P.), a powder prepared from the fresh and healthy thyroid gland of the sheep. It forms a light, dull-brown powder with a faint, meat-like odor and taste, free from any odor of putrescence. It must contain 0.2 per cent. of iodine in thyroid combination. One part of dried gland corresponds to about five parts of fresh gland. Dose, 0.1 G. ($1\frac{1}{2}$ grs.).

Thyroxin ($C_{11}H_{10}O_3NI_3$), not official, forms white crystalline needles insoluble in water, but soluble in the presence of strong alkalies; its melting point is 250° C. Dose 0.2–2.0 mg.

Dried thyroid may be given in powder form or in pills or tablets; care must be taken that it is kept dry to prevent putrefaction, and satisfactory results can be expected only when the preparation has been assayed for iodine. The dose should be small at first (*e. g.*, 1 gr. of the dried gland every evening for the first week of treatment), and should be gradually increased, until improvement sets in or unpleasant symptoms arise. Thyroxin has not been largely used as yet as the supply has been limited and the price high. When it becomes more widely available, it promises the advantages of accurate dosage with a definite chemical compound.

Therapeutic Uses.—Thyroid is not a dangerous remedy, unless in certain cases. In myxœdema, however, it should be used with care, especially if the heart is seriously affected, as the cardiac muscle may be unable to meet the requirements of the accelerated rhythm; several serious cases and one or two fatalities have been recorded in these conditions.

Thyroid extract is useful as a substitute for the normal gland secretion in cases where the latter is wanting or deficient; thus in atrophy of the thyroid in adults (myxœdema), after its extirpation (cachexia thyreopriva), and in its congenital absence or atrophy (sporadic cretinism) the most remarkable improvement follows its use, the patients from a condition of idiocy regaining practically normal intelligence. It is of the first importance to commence the treatment as soon as the condition is recognized and to continue it with careful observation throughout life, for its abandonment leads to a speedy relapse to the former condition. At the same time the dose should not be larger than is necessary and may have to be varied from time to time as circumstances change. Unless the treatment is begun early no complete return to the normal is obtained, although improvement is observed even in neglected cases.

The use of thyroid preparations in these conditions, in which the gland is atrophied, is readily understood. On the other hand it seems anomalous to employ it in cases of enlargement of the gland (goitre). Yet great improvement is seen from thyroid treatment in many of these cases. In goitre the gland is enlarged (hyperplasia), but this does not indicate an excessive formation of secretion, but the reverse; the gland hypertrophies in an effort to compensate for the poverty of its secretion in thyroxin, and when the condition is treated with thyroid the hyperplasia lessens and the gland assumes its normal condition as

FIG. 69

FIG. 70

A case of sporadic cretinism. Fig. 69, before treatment, age twenty-three months, height 28 inches, circumference of the abdomen 19 inches. Fig. 70, after treatment with thyroid extract for five and a half months, height 30 inches, circumference of abdomen 15 inches. (Osler.)

far as the secretory epithelium is concerned, though it may be enlarged through the presence of large colloid masses. The treatment of goitre with thyroid preparations is thus of the same nature as the treatment of thyroid atrophy, for though the gland is enlarged it is unable to fulfill its function. Goitre does not require the permanent use of thyroid as a general rule; the treatment is carried on only until the gland is reduced in size.

The decrease in weight occurring in thyroid medication suggested its

use in obesity, and it has been followed by some loss of weight in a certain number of cases, especially when accompanied by proper dietetic treatment. In many instances it has had little or no effect, however, and the initial encouraging action is seldom maintained when the treatment is continued, the daily loss of weight gradually becoming smaller until it ceases altogether. The amount of fat actually destroyed seems to be trifling, Magnus-Levy estimating that about one pound disappears in ten days, which is much less than can be got rid of by judicious exercise and an appropriate dietary. Besides, the continued use of thyroid in these cases is not altogether devoid of danger. Several authorities state that in some cases the dietetic treatment fails unless it is accompanied at first by thyroid medication; they therefore give a few doses of thyroid to initiate the treatment and continue it by dietetic measures. Many of the antifat remedies put on the market contain thyroid extract and their continued use has led to serious symptoms in a number of cases.

In some skin diseases, especially in psoriasis, it has been of benefit, though not by any means invariably, and in syphilis of old standing some improvement has been seen. This is probably due to the iodine contained, and not to the specific gland secretion. At the same time the peculiar combination in which the iodine is present may perhaps be more easily made use of by the economy than the ordinary inorganic preparations.

The improvement seen in the brain symptoms in myxœdema and cretinism suggested its use in other mental diseases, but the action in the former is due to its substitution for the normal secretion, and little or no effect has followed in ordinary cases of mental disease.

In Graves' disease, thyroid treatment is generally injurious, or at least leads to no improvement. But in some cases very small doses have proved valuable, probably because in those cases the hyperplasia of the gland was passing into atrophy.

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XLII. INSULIN.

In 1885, Mering and Minkowski showed that the removal of the pancreas in animals gave rise to symptoms identical with those of diabetes mellitus in man, and many attempts have been made since to obtain an extract of pancreas which might be of benefit in this disease. Success was attained only in 1922 at the hands of Banting and Best, who obtained a preparation which has been named insulin since it is derived from the islets of Langerhans in the pancreas and not from the general parenchyma of the gland; in fact the pancreatic ferments proper destroy the insulin, and the recent advance is due to a method of extraction by which the insulin is preserved from their deleterious action.

The active principle of insulin has not been isolated in even approximate purity, but may be a complex molecule nearly approaching the simpler proteins in size since it is destroyed by pepsin as well as by trypsin. It is very readily precipitated in a state of adsorption when any of the protein precipitants are used, and is soluble in 80 per cent., but not in 95 per cent. of alcohol. It is rapidly destroyed by alkali, but is more stable in acid solution. Insulin proper is found only in the islands in vertebrates, but it is stated that identical or similar bodies may be obtained from yeast and many growing vegetables and from some of the invertebrates.

Insulin has no apparent effects when given by the mouth since it is destroyed by the digestive ferments. Injected subcutaneously in the rabbit, it causes a remarkable fall in the sugar of the blood from the normal of 0.12 per cent. to 0.05 or 0.03 or less. When only 0.04-0.05 per cent. of glucose is present, the animal becomes restless, and soon clonic convulsions with rotation of the body set in, resembling the convulsions under cocaine. The respiratory quotient rises owing to an increase in the CO_2, indicating an increase in the consumption of sugar. The convulsions can be arrested at once by the injection of glucose, so that they are obviously due to its deficiency in the blood and not to any direct action of insulin on the nervous centres.

Not only the sugar of the blood and tissues is destroyed, but the glycogen of the liver and muscles is drawn upon and may disappear when the convulsive stage is reached.

In diabetic animals and patients, the injection of insulin is followed by a rapid fall in the sugar of the blood, the disappearance of glucose and of acetone bodies from the urine and blood, and general improvement in the symptoms of the disease. After some hours however, as the insulin is consumed in the tissues, the symptoms return, and in order to maintain the normal condition a new injection is necessary every twelve hours.

After a large injection, the same tendency to convulsive seizures is seen in man as in the rabbit, but may be averted by giving glucose by the mouth.

The essential action of insulin is to restore to the tissues the power of utilizing sugar, which is lost in whole or in part in diabetes. With moderate amounts, this may render the metabolism normal; under large doses of insulin, the sugar combustion is so much facilitated that the whole energy is supplied by sugar, which practically disappears from the blood; the glycogen is drawn upon and finally disappears and symptoms of sugar-lack appear in convulsions. The glycogenic function is not directly changed, but merely responds to the needs of the organism for carbohydrate; thus insulin may actually lead to the deposit of glycogen in some conditions.

Several views have been advanced to explain the way in which the sugar-combustion is accelerated by insulin, but they are at present scarcely beyond the speculative stage. There is every reason to believe that the action is in the general tissues and not in any special organ, that the normal pancreas secretes insulin into the blood and that its presence in the muscles and other organs enables them to utilize glucose; in diabetes the supply of insulin fails and the tissues cannot make use of sugar adequately as a source of energy.

Insulin is at present supplied in solution and the amount of active substance can only be ascertained by determining by experiments on rabbits the quantity necessary to reduce the blood sugar and to cause convulsions.

Its use in diabetes has only commenced, but the results are brilliant, the fluid replacing the internal secretion of the pancreas completely as long as it is supplied. Unfortunately this necessitates subcutaneous injections, which must be continued indefinitely. It is possible, however, that at any rate in early cases, the use of insulin combined with reduction of the carbohydrate ration may restore the exhausted pancreas and thus lead of the stay of the disease.[1]

XLIII. HYDRATES AND CARBONATES OF THE ALKALIES.

The hydrates and carbonates of potassium, sodium and lithium owe their pharmacological action entirely to the non-metallic ion, which is so much more powerful than the metal that the latter may be discounted. In the hydrates the active constituent, then, is —OH. The carbonates and bicarbonates dissociate into K- or Na-ions and $—CO_3$, but the latter rapidly combines with the hydrogen of the water to form HCO_3 ions and thus frees—OH, so that the final effect is the same as if a hydrate had been administered, except that the carbonates are less rapidly dissociated than the hydrates, and, less —OH being formed, are less violent in their action. This hydroxyl ion, then, is what induces the alkaline reaction of the solutions and their pharmacological effect, the metallic ion only serving as a means of applying the

[1] See *Macleod*, XIth International Physiol. Congress, Edinburgh, 1923; *Dale*, The Lancet, May 19, 1923, p. 989.

hyroxyl ion, but not affecting the pharmacological action. In other words the alkalinity (hydroxyl ion) of the hydrates and carbonates determines their action; the metal has no practical importance.

It is therefore erroneous to take the hydrates and carbonates as typifying the action of potassium or sodium, for in these the metallic action is much less distinct than in the chlorides, the Cl-ion being practically inert, while the hydroxyl is exceedingly poisonous.

It may be remarked in passing that the importance of the reaction between alkalies and acids lies not in the combination of the metal with the anion of the acid, but in the combination of the powerful hydroxyl ion with the hydrogen ion of the acid. In the effects of potassic hydrate in the stomach, the main importance is to be attached not to the potassic chloride formed, but to the water ($K—HO+H—Cl=K—Cl+H_2O$), for the potassium and chloride ions remain unchanged by the operation, while the hydroxyl and hydrogen ions disappear.

Action.—The pharmacological action of this group is due to their powers of neutralizing acids and of dissolving proteins and changing them to alkali-proteins, and in a less degree to their saponifying fat. They have in addition the ordinary salt-action, and in concentrated solutions withdraw fluid from the tissues.

The solution of proteins by the alkalies and the characters of the compounds thus formed outside the body are well known and need not be entered into here. The same solvent action is observed in the living tissues whenever the hydrates and carbonates come in contact with them in sufficient concentration. The hydrates are, of course, much more powerful solvents than the carbonates, and these than the bicarbonates. In very dilute solutions this solvent action is exercised only on the superficial tissues, but when stronger solutions are used, or when even weak solutions remain long in contact with the tissues, they tend to penetrate more deeply and cause widespread destruction or corrosion. These bodies form soluble compounds with the proteins and are only slowly neutralized by the tissues, so that no such barrier is raised against their penetration as is met by some other corrosives.

Applied to the **Skin** weak solutions dissolve the superficial layer of horny matter and the oily secretions of the glands, and thus cleanse the surface more thoroughly than water or solutions of neutral salts. When applied for some time, they penetrate more deeply and cause some slight irritation and redness. Concentrated solutions dissolve the skin and cause necrosis of the deeper tissues, generally covered by a semitransparent crust which falls off in the course of a few days, leaving an ulcer. The solutions of the carbonates are much less corrosive than those of the hydrates, and induce actual lesion of the skin only under exceptional circumstances, such as very prolonged application.

In the **Mouth** the hydrates and carbonates have a characteristic "alkaline" taste, and dissolve the superficial layers of the lining membrane and the mucus of the secretions. The lips, tongue, and gums assume a bright red color from the irritation and feel soapy to the touch. Concentrated solutions may cause deep corrosion, as in

the skin, while very weak solutions have no effect except the characteristic taste and a reflex flow of saliva. The corrosion caused by strong solutions extends to the throat and œsophagus, and may either prove immediately fatal or may give rise to cicatrices subsequently.

The effect of the hydrates and carbonates in the **Stomach** has been much disputed, and even now it is impossible to explain some of the therapeutic results. Small quantities are undoubtedly neutralized by the hydrochloric acid of the gastric juice and act no longer from their alkalinity, but merely from their effects as salts, if at all. Larger quantities render the contents of the stomach neutral or alkaline and thus prevent gastric digestion. Very concentrated solutions corrode the walls of the stomach and may prove immediately fatal from causing perforation into the peritoneal cavity, while if the corrosion is not so severe, and the patient recovers from the shock and collapse, gastric ulcer and cicatrices may result.

It is very frequently stated that alkalies and alkaline carbonates induce a more rapid secretion of the gastric juice. In fact, some writers go so far as to assert that it is impossible to render the contents of the stomach alkaline except by the use of poisonous doses, because the gastric juice is so rapidly augmented by the alkalies. This belief seems to be founded on the old aphorism *contraria contrariis stimulantur*, which proves to have no greater basis in fact than other similar dogmas. It has been demonstrated experimentally in dogs that alkaline carbonates, whether given by the mouth or injected into the stomach through a gastric fistula, do not influence the gastric secretion, and Reichmann has shown that in man distilled water increases the free acid and the chlorides of the stomach contents as much as an equal amount of an alkaline solution. The only satisfactory examinations of the question, therefore, show that the alkalies have no effect whatsoever on the activity of the secretory glands of the stomach. On the other hand, they may affect the juice already secreted by making it neutral or even alkaline, and may thus render it entirely useless for digestion and disinfection. Of course in hyperacidity of the stomach, the alkalies may be of benefit by lessening the amount of free acid present.

Dilute solutions of the alkalies may act as slight irritants to the stomach wall and thus improve its circulation, and lessen pain, eructation and distention, very much in the same way as other slight gastric irritants, such as the volatile oils. In the case of the carbonates and bicarbonates, this carminative action may be strengthened by the carbonic acid liberated by the hydrochloric acid. In addition, they tend to render the mucus less tenacious, or may dissolve it completely, and thus improve the condition of the stomach. Their effects on the movements of the stomach require further investigation. The pylorus opens normally for the escape of the gastric contents only when the reaction is distinctly acid, and it would therefore be expected that alkali would delay the discharge into the duodenum; but on the other hand neutral fluids pass rapidly through the stomach. It is therefore possible that alkali may delay the evacuation of the stomach when given with

solid food, but may have less effect when taken with abundant water. The arrival of acid in the duodenum normally causes constriction of the pyloric orifice, and this may perhaps be lessened when alkalies are given, particularly in cases of hyperacidity; but the action of alkali on this reflex is still undetermined.

In the small **Intestine** the alkalies have been shown to have an indirect effect, through their diminishing the acidity of the gastric juice. The secretion of the pancreas is normally augmented on the passage of an acid fluid through the pylorus, and if the acidity of this fluid be reduced by the administration of alkalies, a smaller quantity of pancreatic juice is thrown into the intestine. This may again render the digestion less complete, although the greater alkalinity of the intestinal contents tends to increase the efficiency of the pancreatic juice already secreted. On the other hand, in cases of hyperacidity of the stomach, the administration of alkalies may render the contents of the intestine less irritant, and thus tend to allay catarrh.

The alkalies administered in medicinal doses seem to have no effect on the intestinal putrefaction. Kast states that very large quantities (15 G., ½ oz.) increase the putrefaction, probably through neutralizing the disinfectant gastric juice.

The alkalies have been believed to have some special action on the **Secretion of Bile**; thus, it has been supposed that they rendered the bile more alkaline and tended to dissolve the mucus contained in it, that they prevented the deposition of, and even dissolved gall-stones, or that they increased the secretion of bile and thus swept them out of the gall-bladder. All of those theories have been overthrown by the investigations of Stadelmann and his pupils, who have shown that alkaline salts do not increase the secretion of bile, are not excreted in it, and do not cause any change in its reaction. Any effect which the alkaline carbonates or hydrates may possess in hepatic diseases would therefore seem due to their effects in the duodenum.

The prolonged administration of very large doses of the alkaline carbonates and bicarbonates causes chronic gastro-enteritis in animals, and may thus prove fatal to them.

Absorption.—Both hydrates and carbonates disappear rapidly from the stomach and intestine, although the bicarbonate of soda is sometimes credited with some laxative action; this may not, however, be due to the same causes as in the case of the saline cathartics. All alkalies are neutralized by the carbonic acid of the tissues, and circulate in the blood in the form of neutral bicarbonates. This does not alter the reaction of the blood as ordinarily understood; thus if the reaction with litmus be taken before and after the administration of alkali, it is found to be unaltered. On the other hand if the plasma be titrated with an acid, more is required after an alkali has been administered, provided the carbonic acid is driven off during the titration. After alkali treatment then, the reaction of the blood is unchanged but the alkali available for the neutralization of acid is augmented. Even when the alkali administered has been neutralized by the gastric juice, the reserve of

alkali available is augmented because a certain amount of the carbonate of the blood and tissues is spared, which would normally have been used to neutralize the hydrochloric acid before it could be reabsorbed. This condition of augmented alkali can only last a short time, however, as the excretory glands at once proceed to remove the excess. While it is present, the tension of CO_2 in the blood may be lower and the respiratory centre is less active, while the alveolar air contains a higher percentage of CO_2.

It was formerly supposed that the alkalinity (hydroxyl concentration) was actually increased by alkali taken by the mouth and this was believed to influence the **Metabolism**, because many oxidative processes are accelerated outside the body when the reaction is rendered alkaline. But, as has been stated, the alkalinity is not increased in the tissues, but only the available alkali, so that the analogy does not hold. And examination of the metabolism under alkali shows that the tissue change is very little altered. The investigators of the subject have generally confined their attention to the effects of alkalies on the products of metabolism excreted in the urine, and have found the total nitrogen excreted to be unchanged in a considerable number of instances, to be slightly increased in others, and to be diminished in a few individuals. Even in those cases in which an increase is observed in the nitrogen of the urine, it does not always indicate an increase in the nitrogenous metabolism, for the urine is often increased considerably and it is evident that the interchange of the fluids of the tissues and blood is augmented; so that the increased nitrogen of the urine is accounted for by the tissues being more thoroughly flushed out than usual by the alkalies, which act in the same way as the neutral salts.

Although the total nitrogen may be little affected by the administration of the alkalies, the form in which it is combined in the urine and in the blood may be changed. The ammonia of the urine is often diminished in amount, while the urea excretion is correspondingly augmented. This is especially marked in cases in which excess of acid is formed in the tissues or absorbed in any way, and is explained by the fact that this acid is ordinarily neutralized by the formation of ammonia in the tissues (see Acids). When, however, fixed alkali is present in sufficient amount, as when the carbonates are given, the nitrogen which would otherwise have been excreted as ammonium salts, is formed into urea.

The **Uric Acid Excretion** under the alkalies has been the subject of numerous researches, but in the great majority of these very imperfect methods of estimation have been used. In the few cases in which satisfactory methods have been employed, the results have been divergent, the uric acid being sometimes decreased and sometimes increased by the alkalies. In any case the change is trifling in extent, and no inference can be drawn as to the uric acid metabolism from it.

As regards the **Oxidation in the Tissues**, one observer found the oxygen absorbed and the carbonic acid excreted by the lungs increased by the alkalies, while another could detect no change. Another method

of estimating the activity of the oxidation in the tissues has been used by Taniguti and Jawein, who both found that in man the neutral sulphur of the urine is increased by the alkalies at the expense of the acid sulphates; they interpret this as indicating a diminution of the oxidation of the tissues. On the other hand, Heffter and Harnack, using the same method, came to the conclusion that the oxidation in the tissues of the dog is increased by the alkalies. Others have found the oxidation of fat in the tissues accelerated by the administration of alkali.

The only conclusion which seems admissible from these laborious investigations is that the tissue waste is but little affected in amount by the administration of alkalies, and the slight changes observed may vary not only in different species, but in different individuals, and even in the same individual at different times. The cause of this individual variation may be differences in the amount of acid formed in the tissues, but may also be differences in the local effect of the alkalies in the alimentary tract.

The organism rapidly frees itself from the excess of alkali by **Excreting** alkaline salts. This excretion occurs chiefly in the urine, which becomes less acid, or even alkaline in reaction, and in the latter event contains bicarbonate of potassium or sodium. As a general rule, the urine soon regains its acidity, but when fairly large doses are given repeatedly, its reaction may be kept alkaline constantly. This is almost always accomplished in man by the administration of about 10–15 G. (160–240 grs.) of sodium carbonate in twenty-four hours, but some persons require a still larger quantity, while others require less. A temporary alkaline reaction lasting two to three hours may often be induced by a single dose of 2–3 G. The alkalies have the same effect on the excretion of the salts in the urine as the neutral salts—large doses increase the sodium, potassium, and chlorides of the urine.

The injection of alkaline carbonates into the blood induces a more active secretion from the bronchial mucous membrane, according to Calvert, while Rossbach found it to have the opposite effect. It is questionable whether the alkali is excreted here.

The blood of rabbits treated with alkalies is said to be more strongly germicidal than usual, and these animals show greater resistance to infection with anthrax bacilli. These effects are not due to the increased alkalinity of the blood directly, for serum is not rendered more bactericidal when alkali is added to it in test-tube experiments.

When dilute alkaline solutions are applied to **Isolated Organs**, they generally increase their activity for a time, but subsequently weaken it, while strong solutions are immediately poisonous. Thus the ciliary movement of epithelium is accelerated by dilute alkalies, the sodium salts acting more strongly than the potassium because of the poisonous K-ion of the latter. The developing ova of sea urchins divide more rapidly in very dilute alkaline media, but the resulting cells are often irregular in shape. The heart also contracts longer and more strongly when it is perfused by a chloride of sodium solution rendered alkaline by carbonate of soda than when the solution is neutral. Somewhat stronger solutions increase its tonus and eventually cause systolic standstill. The arteries are contracted in the same way by contact with alkaline solutions, and are dilated when acids are perfused through them.

Some of the secretions have also been found to be increased by the presence of alkalies, thus the glands of the frog's skin are stimulated by very dilute alkaline solutions. Loeb has recently observed that the presence of the —OH ion causes frog's muscle to absorb considerable quantities of water from a dilute salt solution, while on the other hand, Hamburger states that the addition of small quantities of alkalies to the drawn blood reduces the size of the blood cells. Zoethout states that some unicellular organisms prove much more resistant to the effects of the withdrawal of oxygen when they are placed in a slightly alkaline medium, and suggests as an explanation that the alkali antagonizes some poison formed during asphyxia.

Strong alkaline solutions destroy all living tissues with which they come in contact.

Preparations.

Potassii Hydroxidum (U. S. P.), Potassa Caustica (B. P.), (KOH), potassium hydrate, caustic potash—dry, white pencils or fused masses, deliquescens in the air and very caustic.

Potassii Carbonas (U. S. P., B. P.) (K_2CO_3), a white granular powder of alkaline reaction, soluble in one part of water. 1 G. (15 grs.); B. P., 5–20 grs.

Sodii Carbonas (B. P.) ($Na_2CO_3+10H_2O$), colorless crystals with an alkaline reaction and taste, soluble in about two parts of water. 0.3–2 G. (5–30 grs.).

Sodii Carbonas Monohydratus (U. S. P.) ($Na_2CO_3+H_2O$), a white crystalline powder without odor and strongly alkaline. Dose, 0.25 G. (4 grs.).

Potassii Bicarbonas (U. S. P., B. P.) ($KHCO_3$), colorless, transparent crystals with a saline, slightly alkaline taste and soluble in three parts of water. 1 G. (15 grs.); B. P., 5–30 grs.

Sodii Bicarbonas (U. S. P., B. P.), ($NaHCO_3$), a white, opaque powder, with a cool, alkaline taste, soluble in 11 parts of water. 1 G. (15 grs.); B. P., 5–30 grs.

Magnesia (B. P.), Magnesii Oxidum (U. S. P.), magnesia (MgO) 2 G. (30 grs.); B. P., 5–20 grs. (repeated), 30–60 grs. (single).

Magnesii Carbonas (B. P., U. S. P.), 3 G. (45 grs.); B. P., 5–60 grs.

These act as aperients in large doses (p. 105) but are largely used as antacids. They are amorphous powders with an earthy taste, insoluble in water.

Magma Magnesiæ (U. S. P.), milk of magnesia, a suspension of magnesium hydrate in water containing 7 per cent. of $Mg(OH)_2$. Dose 10 mils ($2\frac{1}{2}$ fl. drs.).

Numerous alkaline mineral waters are used instead of the pharmacopœial preparations, but as a general rule they contain only very small quantities of the carbonates, and perhaps act more through the large amount of water than through their alkaline reaction.

Therapeutic Uses.—The caustic alkalies are used **Externally** to a limited extent to remove growths, such as warts, from the skin. For this purpose the potash pencils are employed, but they are very deliquescent and it is therefore difficult to limit their action to one spot, and to the superficial tissues. When the desired extent of cauterization has been obtained, the part should be washed with water, or with vinegar or some other dilute acid. The carbonates are also used externally to some extent, chiefly in baths, which they render more irritant to the skin, and in which they tend to soften and remove the superficial horny layers of the epithelium more than ordinary water or solutions of the neutral salts. The carbonates are also applied in strong solution or as a paste in itching skin diseases, and often give relief.

Internally the alkaline carbonates are used for their effect on the stomach, and in cases of hyperacidity relieve the pain and eructation almost instantly. Even where no excessive acidity exists, the alkalies are often beneficial in small quantities, removing distention and discomfort without apparently altering the digestion to any marked extent. The bicarbonate of potassium is more frequently used for this purpose than the others, and the carbonic acid liberated in the stomach may be of importance in the action. Whatever preparation is used, it ought to be well diluted to avoid the irritant action on the stomach wall. Instead of these alkalies, the carbonate and oxide of magnesium may be employed in powder, and possess the advantage of not causing any irritation and at the same time have some aperient action. In cases of hyperacidity the alkalies (antacids) are often given after meals, while when the secretion does not seem to contain an excessive amount of acid they are advised before meals, and may then be combined with other stomachics, such as bitters or volatile oils.

The alkalies are also administered for their effects after absorption, and here the bicarbonate of potassium is most frequently prescribed.[1] Diabetes was formerly treated in this way, in the hope that the oxidation in the tissues would be increased, but there is little reason to suppose that the alkalies have any such effect on the metabolism, and it is now generally accepted that diabetes is not due to a general inability of the tissues to oxidize. Experience, too, has shown that the glycosuria is not lessened appreciably by the use of the alkalies. When, however, diabetes induces an increased acid formation in the tissues, as is almost invariably the case in its later stages, the alkalies are of undoubted benefit in neutralizing the oxybutyric acid formed and thus economizing the alkalies of the blood. In diabetic coma, temporary improvement may often be attained by the use of large doses of alkalies.

In gout, rheumatism and the "uric acid diathesis" generally, the alkalies have been used extensively, partly in the hope that the supposed increased combustion in the tissues would destroy a larger amount of the uric acid, and partly with the idea that the uric acid being neutralized in the tissues, would be excreted more easily and would have less tendency to be deposited. There are some grounds for believing that the alkaline carbonates are of benefit in gout and rheumatism, but neither of these theories seems sufficient to explain their effects, for no increase in the oxidation has been shown to occur, and on the other hand the uric acid is not rendered more soluble in the blood or urine by the quantities of alkali used in therapeutics. In the present position of the uric acid question and of the pathology of these diseases, however, it is futile to attempt to explain their therapeutics, though it may be surmised that the alkalies may influence the formation of the uric acid rather than its excretion. The sodium and potassium salts have been used very largely, and the lithium carbonate has been advised on the ground that lithium urate is about four

[1] The acetates, citrates, etc., may also be used for this purpose (p 552).

times as soluble as sodium urate. Lithium has also been administered in the form of the benzoate and salicylate in these diseases, in order to combine the solvent action of the base with the effects of these acids, but, as in so many other similar attempts, one of the chief factors in the action has been lost sight of; much too small quantities of the lithium compounds have been given to increase the available alkali of the blood appreciably, and besides the salicylate and benzoate do not increase it at all, as they are neutral salts. The lithium salts therefore seem to be superfluous in the treatment of these diseases, since they cannot be given in adequate quantities without eliciting lithium poisoning (p. 522). More benefit is derived from the treatment of gout and rheumatism by the alkaline mineral waters than by artificial preparations, and this is especially marked when patients are sent to the mineral springs. The alkalinity of most of the waters is very slight, and the conclusion is inevitable that the curative agency is not the alkalinity, but the large amount of fluid taken, together with the dietetic and other hygienic conditions.[1]

The alkaline preparations are also largely used for their effects in the urine. In cases of excessive acidity of the urine leading to pain and straining during micturition, the symptoms are relieved by these drugs rendering the fluid less irritating, and this relief is especially marked in irritable conditions of the bladder and urethra. They may also be of value in those cases by rendering the mucus more soluble in the bladder. In gravel the alkalies also give relief, and this has been attributed to their dissolving the uric acid in the urine, or rather to their keeping it in solution in the form of salts. In order to attain this, the urine would have to be rendered alkaline, or at least neutral, and relief is given by quantities of the alkalies which are quite insufficient to do this; this relief in gravel results from the amount of the urine being increased while its acidity is lessened; the inflamed surface of the bladder is thus bathed in a less irritant fluid and the pain is diminished. Attempts have even been made to dissolve calculus in the bladder or in the kidney by treatment with the alkalies, but there is no question that this is hopeless. The solution of the alkalies formed in the urine is extremely dilute, and in fact, except under large doses, the reaction is not even constantly neutral. On the other hand, even the alkaline urates are by no means very soluble bodies, and are formed only with difficulty except in strong alkaline solutions. Again, alkaline urine is very liable to deposit phosphates in the bladder, and thus rather to increase the calculus than to diminish it. Experience has shown conclusively that the alkaline treatment does not remove calculus, although in one or two cases it is stated that soft calculi broke down into

[1] Many other drugs have been introduced as "uric acid solvents," and all have been discredited after trial. Among the more recent of these are *piperazine* (diethylendiamine) and its compounds, *lycetol*, *lysidine*, etc. Strong solutions of these dissolve uric acid in the test-tube, but in the concentration in which they can exist in the tissues and urine they are without action on uric acid. For another recently advocated drug, *quinic acid*, even less can be said, for it has no solvent action even in the test-tube, and it owes its introduction to an erroneous view of the uric acid formation.

fragments under it, from the mucus which held the fragments together being dissolved. The pain and irritation of calculus may be relieved to some extent, however, from the acidity of the urine being lessened.

The alkaline carbonates are also prescribed in cases of jaundice and gall-stone, often with benefit. This is not due to their acting on the bile directly in all probability, for it has been shown that they do not affect it in the normal animal; the improvement may rather be ascribed to their lessening duodenal irritation.

Sodium chloride solution is often injected intravenously in shock and heart failure, and it is found beneficial to add a small quantity of sodium bicarbonate (1:5,000) to it. Alkaline solutions should not be injected hypodermically, as sloughing has been observed repeatedly from this procedure.

The bicarbonate of potassium is often added to other expectorant remedies in the treatment of bronchial catarrh and bronchitis, and is believed to increase the excretion and render it more fluid and more easily expectorated.

The alkaline carbonates may be given as antidotes in poisoning with the corrosive acids, although magnesia is preferable, because it is less irritating to the stomach.

In cases of **Poisoning** with the caustic alkalies, the treatment consists in the administration of dilute acids, of which the organic—acetic, citric or tartaric—are the best. The first is most readily obtained in the form of vinegar. No attempt should be made to pass the stomach tube, as it is liable to pass through the corroded wall of the œsophagus or stomach. General measures, such as central nervous stimulants, warmth, etc., may be taken.

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XLIV. ACETATES AND CITRATES.

As far as their local effects are concerned, the acetates and citrates of the fixed alkalies resemble the chlorides, owing any effect they possess to the salt-action. In the tissues, however, they are oxidized and form carbonates, so that the effects are those of the chloride before absorption, and those of the carbonate subsequently. The oxidation seems to proceed rapidly, and is very complete, over 95 per cent. of the acetate or citrate disappearing, and only some

2–3 per cent. being excreted unchanged in the urine. The available alkali of the blood is increased by the acetates as by the carbonates, and the urine is increased in amount and is less acid or may be alkaline.

The **Acetates** seem almost devoid of specific action—they act only as salts by changing the physical properties of the body fluids, or as alkalies after absorption. The other members of the acetate series have some action, however, for the formate, propionate, butyrate and valerianate of sodium have been shown to be very weak narcotics when they are injected hypodermically or intravenously; this is especially marked in the case of the butyrate. Rather more of the formate escapes unchanged in the urine than of the acetate, while the others are apparently entirely oxidized. The butyrate differs from the acetate in being capable of taking the place of the carbohydrates and fats more completely, and in thus leading to an economy of the nitrogenous tissues of the body. All of the simpler salts of this series are equally rapidly absorbed from the intestine, but the œnanthylate and the caprylate resemble the saline cathartics in being very slowly absorbed.

The **Lactates** resemble the acetates in being almost entirely inactive, but they are rather more slowly absorbed. They are oxidized in the tissues for the most part, and resemble butyrates in limiting the nitrogenous waste, at any rate when they are given in moderate quantities. Lactates are also excreted in the urine, however, in small quantity.

The **Citrates** are absorbed more slowly than the acetates or chlorides and in sufficient quantity act as saline purgatives. The doses ordinarily prescribed, however, are too small to have this effect, and are also insufficient to induce any action after absorption except from that of the carbonate formed. Citrates form indissociable calcium salts and when they are injected intravenously they arrest the clotting of the blood and weaken the heart by throwing the calcium out of action (See Calcium, Oxalate).

Preparations.

Potassii Acetas (U. S. P., B. P.), a crystalline salt of pleasant, saline taste and very soluble in water. 1 G. (15 grs.); B. P., 15–60 grs.

Potassii Citras (U. S. P., B. P.) ($C_3H_4OH(COOK)_3$) 1 G. (15 grs.); B. P., 15–60 grs.

Sodii Citras (U. S. P.) ($Na_3C_6H_5O_7+2H_2O$) 1 G. (15 grs.). Crystalline salts with a cool saline taste, readily soluble in water.

Potassii Citras Effervescens (U. S. P.) 4 G. (60 grs.)

Sodii citrotartras Effervescens (B. P.) 60–120 grs.

These two powders contain bicarbonate of sodium and citric and tartaric acids and effervesce when put in water.

Acetate and citrate of potassium have been largely used as diuretics and in the treatment of gout and rheumatism. They act here exactly as the alkaline carbonates and bicarbonates, but have the advantage of not neutralizing the gastric juice, or in any way affecting the digestion except from their salt-action, which may be minimized by exhibiting them in dilute solution.

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XLV. AMMONIA AND CARBONATE OF AMMONIA.

Ammonia solution and carbonate of ammonia differ considerably from the corresponding hydrates or carbonates of the fixed alkalies in

their effects. The gas evaporates rapidly from its watery solutions, and the carbonate gives off ammonia freely, so that the effects are very similar, although the solution of ammonia is much the more powerful. Owing to its volatility, ammonia penetrates more rapidly and deeply than the fixed alkalies, and at the same time is less corrosive and less enduring in its effects. Applied to the skin in concentrated solution, it may corrode to some extent, but ordinary dilute preparations act merely as rubefacients, like the volatile oils. Even concentrated solutions do not dissolve the epidermis like the fixed alkaline hydrates, but tend to penetrate through it and raise blisters. When inhaled, the irritation of the nasal mucous membrane causes a reflex stimulation of the vasomotor centre, and consequent contraction of the arterioles and augmented blood-pressure, while the respiration is first arrested, and then becomes deeper and fuller. The heart may be temporarily slowed by inhibitory reflexes. Three parts of ammonia in 10,000 of air cause sneezing, pain in the nose, and tears, when inspired by man, and 5 parts in 10,000 are dangerous when inhaled for some time (Lehmann); the symptoms arise only from the local irritation and subsequent inflammation for any ammonia absorbed from the lungs is immediately neutralized.

Concentrated solutions cause corrosion of the mouth, œsophagus and stomach similar to that seen in poisoning with the fixed alkalies, but some of the vapor, passing into the respiratory passages, often sets up spasm of the glottis, or such swelling of the mucous membrane of the larynx and trachea as to induce asphyxia. In cases of ammonia poisoning, therefore, the symptoms often arise, not so much from the gastric corrosion as from asphyxia, and death may occur very suddenly from this cause. The carbonate of ammonia, when swallowed, also causes slight gastric irritation, and in larger quantities nausea and vomiting.

After absorption ammonia and its carbonates are rapidly changed to urea, and thus differ from the fixed alkalies in not increasing the available alkali of the blood, and in having no effect on the urine except to increase the urea and thereby cause some diuresis.

The carbonate of ammonia stimulates the central nervous system when it is injected into the blood in some quantity, but it has no such effect when absorbed from the stomach. (Cf. Ammonium Chloride, page 523.)

Preparations.

Aqua Ammoniæ (U. S. P.), *Liquor Ammoniæ* (B. P.), an aqueous solution of ammonia of 10 per cent. strength by weight. 1 mil (15 mins.).

Spiritus Ammoniæ Aromaticus (U. S. P., B. P.), Aromatic Spirit of Hartshorn, Spirit of Sal Volatile, contains ammonia and ammonium carbonate along with several volatile oils dissolved in alcohol. 2 mils (30 mins.); B. P. 20–40 mins. (repeated), 60–90 mins. (single), in a glass of water.

Linimentum Ammoniæ (U. S. P., B. P.), ammonia liniment, volatile liniment, contains about 2.5 per cent. of ammonia (5 per cent. B. P.).

Ammonii Carbonas (U. S. P., B. P.) is not the pure carbonate, but a mixture of somewhat varying composition, consisting of carbonate (NH_4HCO_3) and carbamate of ammonia ($NH_4NH_2CO_2$). It releases ammonia in the air

and has therefore its pungent taste and smell. It forms translucent, crystalline masses, is very soluble in water and is contained in the aromatic spirit of ammonia. 0.3 G. (5 grs.); B. P., 3–10 grs., in dilute solution.

Ammonia is contained in several of the tinctures of the B. P. (ammoniated tinctures) and in the Linimentum Camphoræ Ammoniatum, etc.

Therapeutic Uses.—The aqueous solutions of ammonia are comparatively rarely employed, although the strong solution has been advised as a vesicant in cases of renal disease, in which cantharides is contraindicated. The ammonia solution has to be covered by a watch-glass in order to prevent its evaporation, and is said to be more painful than other vesicants. The liniment is used as a rubefacient in bruises and in other similar conditions. The gas arising from ammonium carbonate is often inhaled in cases of fainting or collapse, in order to elicit reflex stimulation of the medullary centres. The ordinary "smelling salts" used for this purpose consist of the carbonate reinforced with some of the strong solution and flavored with oil of lavender.

The aromatic spirits of ammonia and the carbonate (in solution) are used as mild gastric stimulants in debility, flatulence and alcoholism, and are very efficient for a short time. Large doses of the carbonate (2 G.) have been used as emetics, and do not cause such prolonged nausea as tartar emetic or ipecacuanha.

The carbonate of ammonia and the spirits or even the ordinary water of ammonia are often given in cases of collapse or sudden heart failure. They are generally administered by the mouth and probably act here not directly on the heart and respiratory centre, as has been supposed, but reflexly from gastric irritation. They have also been injected subcutaneously or even intravenously for this purpose, and here the local action may be reinforced by a direct action on the medulla oblongata. The action lasts only a very short time, but is often sufficient to tide the patient over an acute collapse. In depression from many different causes the aromatic spirits of ammonia is a favorite remedy, and probably owes its value to its gastric action, and not to any changes in the central nervous system. The carbonate is often added to other expectorant remedies to render the bronchial mucous excretion more fluid. (See Ammonium Chloride, page 523.)

Strong water of ammonia is applied locally in snake-bite and is popularly believed to be very efficacious. It has no effect on the toxalbumins of snake poison, and probably is of little or no value in these cases.

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XLVI. ACIDS.

Some acids owe their activity in the organism almost entirely to their acidity, *i. e.*, to the hydrogen ion, which is much more powerful

than the potassium ion, but otherwise stands on the same plane with it; those acids may therefore be treated of together. In the case of many other acids, such as prussic or salicylic acid, the effects of the acidity or hydrogen ion are insignificant in comparison with those of the rest of the molecule or the negative ion, and these are treated along with their salts.

Action.—The acids owe their action on living tissues to their neutralizing alkalies, to their withdrawing water, when in concentrated form, and to their precipitating some of the proteins, more especially the globulins.

Most living matter is neutral or slightly alkaline in reaction, and seems to be incapable of existing in acid media. Exceptions are met with in some of the moulds and in other vegetable organisms which live in somewhat acid solutions, but even these are destroyed by more concentrated solutions, perhaps because the acids precipitate their proteins. Acids are therefore **Protoplasm Poisons** and antiseptics of some power. Hydrochloric acid is found to delay the growth of organisms, and even to destroy the great majority of the less resistant forms in 0.2–0.3 per cent. solution, or in the percentage in which it exists in the gastric juice. The others vary in strength largely according to their acidity, that is, according to the number of hydrogen ions, or the amount of dissociation.[1] The inorganic acids are therefore more powerful as a general rule than the organic, which are less dissociated, and among the latter the simpler compounds are generally more active than those of larger molecule.

When sulphuric or nitric acid is applied to the **Skin** in concentrated form, it acts as a powerful caustic, destroying the epidermis and penetrating to some distance into the skin and subcutaneous tissues, in which it causes necrosis. This is of course accompanied by great pain, and if much of the skin is attacked, by shock and collapse and symptoms similar to those seen in severe burns. Sulphuric acid causes a white, later a brown or black eschar, nitric acid a yellow. Hydrochloric acid is less liable to cause wholesale destruction of the skin, but penetrates the epidermis and raises blisters. The organic acids and phosphoric acid are still less irritant, but cause redness and even blistering when applied in concentrated solution. Dilute solutions of the acids may act as slight irritants to the skin, and often cause a feeling of stiffness and numbness, perhaps from precipitating the proteins.

The corrosive action of the acids is much more marked when they are applied to the less resistant **Mucous Membranes.** Even small quantities of strong sulphuric acid striking the eye are sufficient to destroy the sight.

In the **Mouth, Œsophagus, and Stomach,** the corrosive action is evi-

[1] In some instances the toxicity of an acid is not proportional to its dissociation, however, and Loeb has shown that some acids, notably the slightly dissociated higher organic acids, penetrate cells more readily than some of the simpler ones and thus more than compensate for the fewness of their hydrogen ions.

denced by complete destruction of the mucous membranes which come in contact with the strong acid. The œsophagus and stomach may be perforated, and this, along with the shock and collapse, often proves immediately fatal, or if the patient recovers temporarily, the erosions may give rise to cicatricial contractions and death from inanition. Hydrochloric acid and the stronger organic acids are capable of causing corrosion of the mucous membranes, but this is not so extensive generally as that following nitric and sulphuric acid. The corrosion from acids differs from that from alkalies, in the tissues being shrunken, hard and brittle, while after a caustic alkali they are soft and swollen and have a slimy soapy appearance.

The symptoms of corrosive acid poisoning are intense pain in the mouth, throat and stomach, vomiting and often diarrhœa, shock and collapse, with rapid, weak pulse and shallow respiration. The temperature is often subnormal and death occurs in the course of a few hours. When fuming acids are swallowed, and especially in poisoning with hydrochloric acid, the irritant vapor passing into the respiratory passages may cause spasm of the glottis, or œdema of the larynx, and prove immediately fatal from asphyxia. Even one part of hydrochloric acid vapor in 20,000 of air causes sneezing and pain in the throat and chest.

Dilute solutions of the acids have a characteristic taste, and induce a reflex flow of saliva and an astringent feeling in the mouth and throat, from their causing a coagulation of the superficial layers of proteins. In the stomach they displace any weaker acids from their combinations with bases, and may have some antiseptic action, but do not influence the amount of secretion in any way. The gastric juice is normally acid, containing about 0.2 per cent. of free hydrochloric acid, and this acid reaction is essential to the action of pepsin. Other acids may replace the hydrochloric acid in digestion, but both clinical experience and experiment point to hydrochloric acid as the most suitable acid for use in the stomach. In cases of deficient gastric secretion, the administration of acids increases the acidity of the food as it passes into the duodenum and may thus promote the formation of secretin and consequently the secretion of the pancreas. It is known that food is allowed to pass through the pyloric sphincter only when the reaction is distinctly acid, and that the sphincter closes again when the duodenal mucous membrane is stimulated by acid; when the food in the stomach is rendered strongly acid, it is found to leave the stomach more slowly, though the movements of the organ appear to be more rapid and stronger than normally.

The acids are absorbed from the alimentary canal fairly rapidly in most cases. In the **Blood and Tissues** they do not exist as acids but as salts, for the reaction of the blood must remain slightly alkaline throughout life, and if sufficient acid be given to neutralize the alkalies of the body, the animal dies before the blood becomes neutral, although after death it may be found to be acid. The means provided by the economy to neutralize acids differ in different animals; in the herbivora

the fixed alkalies of the blood and tissues are called upon chiefly, and if more acid be absorbed than can be neutralized by these, the animal dies; in the carnivorous animals and in man, a further protective mechanism exists, for in these ammonia is liberated by the tissues, and serves to neutralize the acid, and thus saves the fixed alkalies. The difference is relative and not absolute, however, for the herbivora also develop some ammonia, and the carnivora employ some of the fixed alkalies to preserve the normal reaction of the tissues. Man seems to stand midway between the two classes, for while ammonia appears in the urine after acid absorption, the fixed alkalies are also present in excess. Much larger amounts of dilute acids may therefore be absorbed without serious symptoms by man and by the carnivora than by the herbivora. The explanation of this difference between the flesh-eating and the plant-eating animals is to be found in the nature of their food. The flesh-eaters are accustomed to the formation of some acid in their tissues, because the alkalies of their food are insufficient to neutralize the acids formed by the oxidation of the organic matter, and they would gradually be deprived of all their alkaline salts, therefore, were they not protected by the formation of ammonia. On the other hand, the herbivorous animals absorb much larger quantities of the organic salts of the alkalies in their food, and these forming carbonates in the body, serve to neutralize what acid is formed in the tissues. In ordinary circumstances, therefore, they have no need to protect the fixed alkalies, and are unprovided with any mechanism for this purpose. When an excess of acid is absorbed, they neutralize it by means of the fixed alkali of the tissues and blood, and the slight change in the reaction reduces the power of the hæmoglobin to transport carbonic acid from the tissues to the lungs. Thus in acid poisoning in rabbits, the alkali of the blood has been found to be so greatly reduced that the blood instead of containing some twenty-five volumes of carbonic acid per cent., carried only two volumes per cent. or very little more than could be dissolved in the same amount of water. When this occurs, the tissues are unable to rid themselves of their carbonic acid, and a series of symptoms follow, commencing in deep, labored, rapid, afterwards shallow, respiration; the heart is weak, a condition of collapse follows, and eventually the respiration ceases, the heart continuing to beat for some time longer. The injection of sodium carbonate, even in the last stage of intoxication, is followed by rapid recovery, from the restoration of the normal reaction of the blood and tissues, while other carbonates are not so useful, owing to the action of the basic ion. In carnivora and man, the absorption of dilute acids does not alter the available alkali of the blood so much, but here also the transport of CO_2 is delayed, and slight exertion causes breathlessness and exhaustion.

Acidosis.—Much interest has been developed in recent years in the supposed deleterious effects arising from the action of small quantities of acids on the animal economy. It may be stated at once that these effects have been greatly exaggerated. The acid is at once neutralized by the alkali bicarbonate of the blood, the resulting CO_2 stimulates the

respiratory centre and is got rid of by the increased ventilation of the lungs. A smaller amount of alkali remains in reserve in the blood, but this is remedied by the excretion of acid salts by the urine, so that the reserve quickly rises again. The only important symptom arising from a considerable reduction of the alkali reserve is breathlessness on exertion. If the alkali is further drawn upon by very large amount of acid, death follows as has been described above.

The salts formed in the blood and tissues after the absorption of acids are rapidly **Excreted** by the kidneys, which, however, retain as much alkali as possible in the body and thus excrete the salts in an acid form. Hence there arises in some cases irritation of the kidneys, with albumin, and even blood, in the urine, which is rendered more acid than usual and causes a sensation of heat and smarting in the bladder and urethra. In the herbivora the reaction changes from alkaline to strongly acid, and large quantities of the salts of the alkalies appear, while in the carnivora some increase in the sodium and potassium of the urine occurs along with a much greater increase in the ammonia. The total nitrogen is somewhat increased from the large amount of ammonia, but the urea is slightly decreased. Some authors have found an augmented excretion of lime in the urine, while others state that it is less than usual.

Not infrequently fatty degeneration of the heart, liver, muscles or kidney has been observed in corrosive acid poisoning, when the patient survived for a few days, and Fraenkel and Reiche found a form of necrosis of the renal cells in these cases. These changes are not due to free acid in the blood, but to the impaired tissue respiration probably.

The prolonged treatment of animals with acids has been found to be followed by anæmia and loss of flesh and strength, which are probably attributable to the disturbance of the digestion and not to any specific action of the acids.

The limits within which tissues live and grow are given as between pH-4 on the acid and pH-10 on the alkaline side, and acids applied directly to them lessen their vitality, and unless there is sufficient alkali present to neutralize them, soon destroy it entirely, In some cases they tend to cause a temporary increase in activity at first; thus the cilia of ciliated epithelium have been found to move more rapidly at first in very dilute acids and then to cease all movement, while muscle seems to be rendered weaker and less irritable at once. As in the case of alkalies, Loeb finds that dilute acid causes muscle to imbibe more water than salt solution does, and Hamburger finds that the red blood cells are increased in size by the addition of small quantities of acid to the blood outside the body. The frog's heart is weakened and dilated by the addition of acid to a perfusing solution, and the muscular wall of the vessels and other organs are first contracted and then dilated but the results seem to vary with the other constituents of the fluid (Heymann). The addition of acids to the blood tends to agglutinate the red cells and to form acid hæmatin.

Therapeutic Uses.—The acids are used in medicine only to a limited extent, and most of the official preparations might well be dispensed with.

They may be employed to give flavor to draughts in fever and in the thirst of diabetes, the most popular forms being those formed from fruits, such as lemons, limes, or grapes. The taste is due to the sugars, acids and volatile

oils of the fruits, and is modified by the presence of inert colloid substances, such as the pectins. The acids, of which citric, tartaric and malic are the chief, are very important factors in the effect, for if these be neutralized, the fruit juices become insipid, and do not quench thirst so thoroughly. The so-called grape cure, in which very large quantities of grapes are eaten, owes most of its value to the large amount of water taken, although the acids and salts may act as aperients in the same way as the saline cathartics. Instead of the fruit juices, carbonic acid waters may be advised, and occasionally other acids, such as phosphoric or sulphuric, are prescribed to give flavor.

Acids are also used in certain forms of dyspepsia in which the hydrochloric acid of the stomach is deficient. Hydrochloric acid is most frequently prescribed for this purpose, and is certainly more efficient than the others in test-tube experiments on digestion. The forms of dyspepsia thus treated are generally those arising from a sedentary life or in the course of convalescence, and acid is often prescribed along with the bitter stomachics and is to be taken about half an hour before meals. Irritation of the stomach, or hyperacidity of the gastric juice, is, of course, a contra-indication.

Acid may also be used to make the urine acid, and thus to render it less favorable to the growth of microbes. For this purpose the acid sodium phosphate is used; this salt is very often given along with hexamethylentetramine, which acts only in acid urine (p. 165).

In cases of alkaline poisoning, the acids are the natural treatment; the organic acids should be preferred for this purpose, as they are less liable to cause additional corrosion, and acetic acid in the form of vinegar is more likely to be at hand than any other.

In every case in which acids are prescribed internally, they have to be given largely diluted, as otherwise they irritate the throat and stomach. They are taken through a glass tube, in order to prevent as far as possible their action on the teeth.

Strong acids have some effect in arresting hæmorrhage (styptics) when applied directly to the bleeding point, but are much inferior to some of the metallic salts, such as the iron perchloride.

Externally, the acids are used to some extent as corrosives, strong nitric acid being not infrequently used to destroy small tumors, to cauterize the os uteri and for similar objects. Its action is more easily localized than that of potash and on the other hand is more powerful than the metallic salts, such as silver nitrate and zinc chloride. In dilute solution, they are sometimes applied to the skin to lessen excessive local sweating and diluted vinegar is often used to sponge fever patients.

In cases of corrosive **Poisoning** with acids, the first indication is to neutralize the acids as far as possible by giving alkalies. These ought not to be in themselves corrosive, and the best antidote is therefore the insoluble magnesia and magnesium carbonate. Lacking these, the most readily accessible alkali is the best, and the lime may be scraped from the walls or ceilings, or chalk, soap, or wood ashes may be given. The walls of the stomach and œsophagus may also be protected by giving milk or white of egg, or the acid may be rendered less corrosive by diluting it with large quantities of water.

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Compare Alkaline Hydrates and Carbonates. For the specific effects of the anions of the acids, see chlorides, phosphates, acetates, oxalates, etc.

Sulphuric Acid is one of the most corrosive acids when it is applied in concentrated form, and often induces complete charring of the tissues, and a coal-black slough.

Acidum Sulphuricum Dilutum (U. S. P., B. P.) contains 10 per cent. of absolute sulphuric acid. 1 mil (15 mins.); B. P., 5–20 mins.

Acidum Sulphuricum Aromaticum (U. S. P., B. P.) is an alcoholic solution flavored with ginger and cinnamon. The U. S. P. preparation contains 20 per cent., the B. P. preparation 11.4 per cent. of sulphuric acid. 1 mil (15 mins.); B. P., 5–20 mins., in a glass of water.

The sulphuric acid preparations are not largely used. The aromatic acid is sometimes given as a prophylactic and remedy in lead poisoning, but it is probably of little value here.

Nitric Acid is equal or superior to sulphuric in its corrosive action. It stains the skin and tissues a bright yellow or yellowish-brown, and this serves to distinguish cases of poisoning under the two acids.

Acidum Nitricum (U. S. P., B. P.) contains 68 per cent. of absolute nitric acid (HNO_3) (B. P. 70 per cent.).

A glass rod dipped in concentrated nitric acid is used as a corrosive.

Hydrochloric Acid is less corrosive than the two preceding acids, and tends to cause blistering on the skin rather than necrosis. It may cause actual loss of substance, however, when applied to the mucous membranes in concentrated form, and stains the mouth a whitish color.

Acidum Hydrochloricum Dilutum (U. S. P., B. P.), contains 10 per cent. of hydrochloric acid gas. 1 mil (15 mins.); B. P., 5–20 mins. in a glass of water.

The diluted acid is prescribed in dyspepsia in which there seems a deficiency of the natural acid secretion. In cases of diarrhœa in which excessive putrefaction of the intestinal contents is present, it may be of benefit when prescribed along with other drugs; this action is probably explained by its disinfecting the stomach contents, as the hydrochloric acid of the gastric secretion normally does. It is said that hydrochloric acid prevents the lactic fermentation in 1:1000 dilution, and that in addition to its action on the digestive ferments it increases the peristalsis of the stomach.

Nitrohydrochloric Acid is formed by mixing hydrochloric and nitric acid, and contains not only the original acids, but a number of decomposition pro-

ducts, such as chlorine, nitroxychloride (NOCl) and nitrous acid. The strong acid (aqua regia) is the most powerful solvent and oxidizing agent known, dissolving such refractory metals as platinum and gold.

The diluted acid alone is used in therapeutics (Dose 15 mins.) and has some reputation in liver diseases and jaundice. This appears to be a survival of the ancient doctrine of signatures, according to which the therapeutic value of a drug was indicated by its color, shape or other similar qualities; thus red-colored roots were used for diseases of the blood, and yellow fluids, such as nitrohydrochloric acid, in jaundice, a yellow disease.

Phosphoric Acid is much less corrosive and irritant than the other mineral acids, but in large, concentrated doses may cause gastro-enteritis. It has been used to some extent to form cooling draughts in fever. The acidity of the urine arises from the excretion of acid phosphates for the most part, and may be increased by the administration of *Sodii Phosphas Acidus* (B. P.), NaH_2PO_4. This consists of colorless crystals with an acid saline taste, readily soluble in water. Dose, 30–60 grs.

The **Organic Acids** have a much less marked local action than the inorganic, causing little or no corrosion unless when applied to mucous surfaces in very concentrated form. They are absorbed as salts of the alkalies, but do not as a general rule reduce the available alkali of the blood or render the urine more acid, because they are oxidized to carbonates in the tissues. Those which are not burned in the tissues, such as oxalic acid and the aromatic acids, have the same effects as the inorganic acids on the reserve alkali and the urine.

Acetic Acid applied in concentrated solution to the skin causes irritation and congestion and eventually blistering, but does not induce necrosis except of the most superficial layers. The congestion is often followed by marked pallor instead of by blistering; and this has been explained by contraction of the vessels, but may be due to a precipitation of the proteins of the skin. In the mouth and stomach it acts as an irritant, causing vomiting, great pain, collapse and even death; the epithelium is found thickened and occasionally contains hæmorrhages. Dilute acetic acid (vinegar) has little effect apart from its acid taste, and is used largely as a flavoring agent and condiment. The prolonged use of large quantities may, however, give rise to gastric irritation and to loss of appetite and weight.

Acidum Aceticum (U. S. P., B. P.) contains 36 per cent. of absolute acetic acid U. S. P., 33 per cent. B. P.

Acidum Aceticum Dilutum contains 6 per cent. of absolute acetic acid U. S. P., 5 per cent. B. P 2 mils (30 mins.); B. P., ½–1 fl. dr.

Acetic acid is sometimes applied to the skin as a slight local irritant in contusions, and in very dilute solutions to cool the surface and to prevent excessive local perspiration. It has been used as a styptic in slight hæmorrhage, and may be inhaled for this purpose in epistaxis. Vinegar is also inhaled in cases of fainting, in order to induce reflex stimulation of the vasomotor centre through irritation of the nostrils. In cases of poisoning with alkalies vinegar is often the most convenient acid, and in addition is less likely to do harm than the inorganic acids.

Acetic acid itself is not used as a corrosive, but one of its derivatives, trichloracetic acid (CCl_3COOH), U. S. P., has been employed with good results.

Formic Acid resembles acetic acid in most points, except that it is more volatile and more irritant, that less of it is oxidized in the tissues, and that given in large quantities it is said to induce nephritis. It is quite useless in therapeutics.

The other acids of the acetic acid series resemble acetic acid in their effects, but become less irritant as they become more complex and less easily dissociated.

Lactic Acid resembles acetic acid in its behavior in the organism. It was suggested at one time that sleep following muscular exertion was due to the lactic acid formed in the muscles, and this acid was therefore recommended as a hypnotic, but has been shown to be of no value for this purpose. Rickets, rheumatism and other diseases were also at one time attributed to the excessive

formation of lactic acid in the tissues, but this theory is only of historical interest. Lactic acid has been used as a caustic application to malignant ulcers and diphtheritic membranes.

Oxalic Acid is frequently used as a poison by suicides, either as such or as the acid potassium salt (salt of sorrel or essential salt of lemons). Poisoning has repeatedly occurred from oxalic acid having been mistaken for magnesium sulphate, which it resembles in appearance. The symptoms are those of acid poisoning, along with the specific effects of the oxalates. Oxalic acid is not used in therapeutics.

Tartaric Acid induces symptoms of gastric irritation when taken in large doses, and has been the cause of fatal poisoning in a few cases. It is slowly absorbed, and some of it escapes combustion in the tissues and is excreted in the urine in the form of acid tartrate. (See Tartrates, page 109.)

Acidum Tartaricum (U. S. P., B. P.) ($H_2C_4H_4O_6$), colorless crystals very soluble in water. 0.5 G. (8 grs.); B. P., 5–20 grs.

Tartaric acid is prescribed with the carbonates and bicarbonates to form effervescent draughts; the tartaric acid ought to be slightly in excess in order to lend its pleasant acid taste, the usual proportion being about eight parts of acid to seven parts of sodium bicarbonate. These effervescent mixtures formed with the tartrates act as saline cathartics in large doses (see page 110). Tartaric acid may be prescribed in dilute solution with sugar and a drop of volatile oil as a lemonade, which is cheaper than that formed with citric acid.

Citric Acid resembles tartaric acid in its action, but appears less irritant, and no case of serious poisoning is recorded from its use. It is slowly absorbed like tartaric, but seems to be almost entirely oxidized in the tissues.

Acidum Citricum (U. S. P., B. P.) ($H_3C_6H_5O_7+H_2O$) resembles tartaric acid in its properties for the most part. 0.5 G. (8 grs.); B. P., 5–20 grs.

Syrupus Acidi Citrici (U. S. P.) is ordinary syrup to which 1 per cent. of citric acid and tincture of lemon-peel have been added, and is used only as a flavor.

Citric acid and the citrates when added to drawn blood prevent clotting by combining with the calcium in a practically non-dissociating salt. When administered by the mouth it has no such effect on the circulating blood, and its use to lessen clot formation in the body is based on erroneous observation.

Citric acid is used to form lemonades and effervescent draughts. For lemonade 2-4 parts of citric acid may be dissolved in 1000 parts of water, some sugar and a few drops of volatile oil being added. For effervescent solutions about 8 parts of the acid may be prescribed along with 7 parts of bicarbonate of soda, with directions to dissolve the two powders separately, mix the solutions and drink while effervescing. In large quantities this mixture acts as a saline cathartic; in smaller quantities it may be used to increase the alkali of the blood, and to render the urine less acid.

Lime juice and lemon juice, which contain considerable amounts of free citric acid, are generally preferred to the pure acid for lemonades to quench the thirst. Lime juice has been found of great benefit as a prophylactic in the treatment of scurvy, but this is not due to the citric acid, but to the "vitamin" of the fruit juices (p. 509).

XLVII. CALCIUM.

The salts of lime are present in very large amount in the tissues of animals, and considerable interest attaches to their absorption, excretion, and general action. They form the great mass of the inorganic constituents of the bones and teeth of the vertebrates and of the shells of the invertebrates. In addition it has been shown of recent years that they are present to a considerable amount in the soft tissues and

are, in fact, essential to most forms of living matter, and to the activity of certain ferments.

Calcium and the other alkaline earths differ from the alkalies in possessing comparatively few very soluble salts, and they seldom effect such changes in the physical properties of the fluids of the body as have been described under salt-action and chloride of sodium. Even the soluble salts penetrate with greater difficulty into the various tissues of the body, which seem to have less affinity for them than for the salts of the alkalies. They precipitate colloids, such as the proteins, in more dilute solutions than the salts of the alkalies, and the precipitate is not redissolved by dilution with water. This precipitation of proteins appears to account for the pain and irritation which follow the subcutaneous injection of the more readily dissociable salts such as the chloride.

Action.—The soluble lime salts are **Absorbed** with great difficulty from the stomach and intestine and retard the absorption of fluid. They would presumably have a cathartic action were they not thrown out of solution very readily by the alkaline fluids. In addition calcium forms insoluble salts with all of the cathartic anions, so that no such double effect can be obtained as is seen from magnesium sulphate. (See Saline Cathartics, page 105.) The greater proportion of the lime taken either in the food or as a remedy, unquestionably leaves the body in the stools unabsorbed, while a smaller quantity of it is taken up from the alimentary canal whether the lime be administered in a soluble or in an insoluble form. This circulates in the blood, chiefly as diffusible salts (bicarbonate) but partly in combination with proteins, and is slowly excreted, unless there is a deficiency in the supply of lime, when it may be utilized by the tissues. When larger quantities are thrown into the blood by intravenous or hypodermic injection, the calcium of the blood remains abnormally high for a short time, but all the calcium thus injected is not in the circulation throughout its stay in the body. Some of it is temporarily deposited in some unknown organ, and is gradually withdrawn and excreted after the first excess is eliminated.

The lime is **Excreted** in part in the urine, but for the most part through the epithelium of the large intestine. The relative amounts excreted by the kidney and bowel seem to be determined by the quantity of available phosphates among other factors; if these are present in large quantities in the blood, the calcium is excreted mainly in the bowel in the form of calcium phosphate. Excess of chlorides in the body fluids has the opposite effect, more calcium appearing in the urine. The elimination of calcium thus appears to vary with the character of the combinations which it can form; if these are soluble they appear in the urine, while the insoluble ones tend to pass into the stools. The administration of calcium increases the elimination of magnesium in the urine, and similarly magnesium absorbed leads to a larger excretion of calcium in the urine, while that in the faces may be diminished. Calcium lessens the phosphates of the urine, and therefore its acidity, by forming insoluble phosphates in the bowel, and thus preventing the absorption of the phosphates of the food.

The calcium absorbed has no obvious effects; constipation is often induced by lime, but it is uncertain whether this arises from action on the intestinal neuromuscular apparatus, or is the result of the calcium precipitating the superficial protein in the bowel and thus forming a protective covering over the epithelium and lessening the reflex peristalsis (compare tannin group). Except under special circumstances, the calcium of the food is always sufficient to supply the needs of the organism, so that lime salts given as remedies have after absorption no specific action due to the calcium, but owe their activity to the anion exclusively. Thus, calcium bromide may have some effect if absorbed, but this effect is due to the bromide ion, and would be the same if an equal proportion of sodium bromide were taken up by the blood.

The action of calcium on isolated organs is complicated by the fact that it must always be applied along with sodium in order to maintain the osmotic equilibrium, and sodium appears to modify the lime action considerably, as will be discussed on a later page. But calcium appears to depress the neuromuscular connections in striated muscle like curara, and later to weaken the muscle itself. The removal of lime is said to increase the irritability of the terminations of the autonomic nerves in mammals; on the other hand the vagus is stated to lose its inhibitory action on the heart perfused with calcium-free salt solution.

Soluble calcium salts injected directly into the bloodvessels seem to be poisonous, their action resembling that of digitalis in some respects. They first accelerate and strengthen the heart, and in large quantities bring it to a standstill, and also have a marked effect in contracting the vessels when perfused through them. In this way they may sometimes diminish the diuresis and glycosuria in animal experiments. Large quantities injected intravenously contract the pupil to pin-point size, apparently from action on the fibres of the sphincter muscle, for atropine has little effect on the myosis. Asphyxia causes dilatation after calcium, however, in the same way as in morphine poisoning. These effects are absent when the salts are taken up from the bowel, mainly no doubt owing to their slow absorption, which prevents their attaining a high concentration in the tissues.

There is some not altogether convincing evidence that lime salts lessen the permeability of the cells of the tissues; for example, it is stated that in the presence of traces of calcium dried cells take up less water. This view has been further developed by Chiari and Januschke, who state that when an animal has been treated with lime salts the intravenous injection of iodides does not induce pleural effusion and œdema, while it has this effect in untreated animals; the statement that strong irritants may be applied to the conjunctiva without swelling and effusion in these treated animals is certainly erroneous, as was shown repeatedly in experiments on the poison gases during the Great War. The whole theory of the specific action of calcium on effusion and inflammation requires further investigation before it can be accepted.

Lime Starvation.—Excess of calcium in the organism is therefore little to be apprehended from the ordinary methods of administration, and lime salts are seldom used in therapeutics to induce changes through their presence in excess in the blood, like other remedies, such as morphine or strychnine. Another question arises, however, namely, whether the organism may not be rendered abnormal by a deficiency in the supply of lime, and whether this deficiency may be remedied by the administration of calcium salts.

The effects of a deficiency of lime in the food have been the subject of several very careful investigations, and while the adult animal does not seem to suffer greatly from a very considerable reduction of the calcium of the food, young growing animals develop marked abnormalities, resembling closely those observed in rickets and osteomalacia in the human subject. In lime starvation, as in rickets, there is a lessened deposit of lime in the bones, which retain their cartilaginous consistency and show other deviations from the normal condition; in rickets the bones alone are involved, while in animals deprived of calcium the soft tissues also show a lessened content of lime salts. Deficiency of the lime in the food naturally affects young animals more than adults, because the former require calcium to build up the growing skeleton. But if the lime of the food is greatly reduced while a special demand is made on the lime reserve of the body, the bones in the adult may also suffer; thus in pregnant animals, in which lime has to be supplied for the fœtal skeleton, weakness of the bones of the mother simulating the osteomalacia of human pregnancy has been observed when the lime of the food was reduced.

The effects of the withdrawal of lime have been studied in some **Isolated Organs.** Thus Ringer compared the behavior of the frog's heart when perfused with solutions of the salts of the alkalies with that of one perfused with the same solutions to which minute traces of lime were added, and found that the efficiency of the heart was much increased and that it survived longer under the latter conditions; Locke has shown that a similar relation exists between the mammalian heart and the inorganic elements of serum. Lime salts exercise a similar effect in voluntary muscle, which survives much longer when perfused with salt solution containing calcium than when sodium chloride solutions alone are used. Both the heart and skeletal muscle eventually cease to contract on electrical stimulation when perfused with sodium chloride solution alone, but recover when traces of lime salts are added to it. In the same way, the irritability of the frog's nerve persists much longer in salt solution containing a lime salt than in unmixed salt solution, and may be restored by the addition of lime, when it has disappeared under the prolonged action of the 0.6 per cent. chloride of sodium solution. Ciliated epithelium continues to wave rhythmically longer in lime solution than in distilled water, in which it swells up and rapidly loses its activity. This probably explains the observation that some fish die very soon in distilled water but survive in water in which traces of lime are present. Lime is also necessary for the development of various ova; for instance, frog spawn kept in water devoid of lime salts fails to develop, or develops abnormally.

Lime salts are also indispensable in some processes which are not dependent on the presence of living cells. Thus rennet does not coagulate milk except when a lime salt is present, and the **Coagulation of the Blood** may be prevented by precipitating its calcium salts in the form of oxalates. Hammersten has shown that the lime salts are not necessary to the formation of fibrin, for this occurs in oxalate

solutions if fibrin-ferment is added to fibrinogen. But the fibrin-ferment is not formed except in the presence of calcium salts, and when oxalates are added to the blood before this ferment is developed, they prevent its formation and hinder clotting. When lime salts are added, the ferment is liberated and coagulation occurs at once. In other words, lime is not necessary for the activity of the fibrin-ferment, but for its development from the prothrombin or zymogen, in which it exists in the circulating blood. Lime salts taken by the mouth do not accelerate the clotting of blood.

Other ferments act in the absence of available lime salts. Thus pepsin digests when instead of hydrochloric, oxalic acid is added to it, but it is unknown whether pepsin is formed from pepsinogen in the absence of lime. The trypsinogen of the pancreas may be changed to trypsin by lime salts.

The higher organisms, both animals and plants, have thus been shown to require lime for some of their functions, and it is probably necessary for many others in which its importance has not yet been recognized. The lowest forms of life, however, including the bacteria and some of the moulds, seem to be able to live without it. To induce the effects of lime starvation, it is not always necessary to withdraw lime from the food, for they may be caused by the presence of any substance which prevents the dissociation of the calcium ion, such as sodium oxalate, citrate or fluoride. Food containing large quantities of oxalate salts has in some cases induced symptoms in animals resembling those of lime starvation, and it seems probable that most of the symptoms of fluoride action are also explicable from their precipitating the lime salts of the food and of the blood. (See Oxalates and Fluorides.)

Balanced Salt Solutions.—A curious relationship has been shown to exist between the calcium and potassium salts. Thus when a frog's heart is perfused with sodium chloride solution containing a trace of calcium, the movements are not entirely normal, the contraction being somewhat prolonged and the relaxation much retarded. If a trace of potassium chloride is added, however, the contraction becomes normal in character. On the other hand the effect of potassium on the frog's heart is antagonized by the addition of lime. The same holds true for voluntary muscle, the salts of calcium tending to neutralize the effects of potassium, and *vice versa*, and in several other relations an antagonism has been observed between these two metals. Another marked antagonism has recently been studied by Meltzer, who shows that toxic quantities of magnesium can be completely neutralized by calcium. And, as the symptoms of magnesium poisoning in mammals are characteristic, the recovery of animals when calcium is injected is very striking; magnesium induces narcosis and anæsthesia, which is immediately counteracted by calcium, and the animal assumes its normal posture.

Another question that has excited much interest recently is the relation between sodium and calcium. It has already been noted that the frog's heart perfused with sodium chloride solution soon ceases to beat, but can be restored by the addition of calcium and potassium to the circulating medium. The ordinary explanation (Ringer, Howell) is that the calcium and potassium are necessary to the activity of the heart and that when pure salt solution is perfused these elements diffuse into it and are lost from the heart muscle; this diffusion is prevented if calcium and potassium be contained in the solution, and the heart, retaining the salts essential to its activity, continues to beat. Another

explanation has been offered by Loeb, who supposes that the lime and potassium are not directly essential, but that they neutralize the poisonous effects of sodium. This poisonous action of sodium has not been generally recognized, but is well shown by the behavior of a small fish (fundulus) living in salt water, which can be transferred to distilled water without injury, thus showing that neither sodium nor calcium is necessary in its environment. But if it be put in sodium chloride solution of the same strength as sea water, it dies, so that sodium is poisonous to it unless when antagonized by the other constituents of sea water; the essential elements are calcium and potassium, for when these are added to the injurious sodium solution, the fish lives as well as in sea water. This series of experiments certainly forms a strong support for Loeb's theory that calcium is not directly essential to rhythmic movement, but only neutralizes the effects of sodium. On the other hand, the calcium salts themselves are poisonous when they are not counterbalanced by sodium and potassium; in this, as in many other instances, there must be maintained between the inorganic constituents of the surrounding fluid an equilibrium, such as exists in sea water in the case of the fundulus, and in the blood plasma in the case of the heart and other organs.

The salts of the alkaline earths are said to inhibit the hæmolytic action of certain serums, while those of the alkalies have not this effect when applied in the same concentration; this may perhaps be connected with the tendency the former have to coagulate proteins. The formation of protein combinations is apparently the explanation of the disappearance of lime salts when they are perfused through organs or when pieces of tissue are soaked in them. Cartilage seems to combine more readily with lime than the other tissues.

Therapeutic Uses.—Calcium salts are used in medicine for a number of different purposes; thus the alkaline preparations may be prescribed to lessen the acidity of the stomach, and the oxide may be employed as a caustic. But these owe their use, not to the calcium ion, but to the other part of the molecule—the anion. As a matter of fact, calcium has few important effects of its own and is seldom prescribed for any action which it might have on the living tissues. The question has been raised, however, whether calcium may not be given therapeutically to supply a deficiency of lime in the body. The particular conditions which have been treated on this theory are rickets and osteomalacia, in both of which there is unquestionably too little lime in the bones, and the treatment has been thought to be rational, because symptoms similar to those of rickets have been induced in young animals whose food contained too small a proportion of lime. There is no question now, however, that rickets and osteomalacia are not due to a deficiency of lime in the food or in the blood, but to the failure of the lime to be deposited in the bone. And no benefit is obtained by increasing the lime in the food. The true treatment of rickets is the supply of vitamin A in the food and the exposure to sunlight or ultraviolet light; this is sufficient to prevent or cure the disease, without any further change in the food or in the general hygienic conditions.

It has also been proposed to treat with lime cases in which the blood is less capable of clotting than normally—particularly hæmophilia, and the treatment has been extended to aneurism, hæmoptysis, and gastric and intestinal hæmorrhage. In hæmophilia there is no deficiency of lime in the blood, however, and still less is this the case in aneurism

and hæmorrhage. And the administration of lime by the mouth or otherwise does not accelerate or in any way alter the clotting of blood. Finally no distinct clinical results have been obtained by careful observers, and the treatment may be dismissed as erroneous.[1] A still further development of the theory has led to the use of calcium in the most diverse conditions, in which it was suggested that the symptoms arose from excessive transudation of lymph into the tissues; and the clinical results are equally disappointing.

MacCallum has recently stated that in dogs from which the parathyroid glands have been removed, the lime content of the brain and blood may be very much diminished, and that the symptoms of tetany which arise after the operation may be relieved by lime salts given intravenously or by the mouth. A few cases of tetany in man also improved under treatment with calcium salts.

Preparations.

Calcii Chloridum (U. S. P., B. P.) ($CaCl_2$), a white salt with a sharp, saline taste, very deliquescent and soluble in water. 0.5 G. (8 grs.); B. P , 5–15 grs.

Calcii Lactas (U. S. P., B. P.) ($Ca(C_3H_5O_3)_2,5H_2O$), a white, almost tasteless powder soluble in 18.5 parts of water. 0.5 G. (8 grs.), B. P. 10–30 grs.

Calcium chloride is the salt which gives the least complicated calcium action, and is consequently seldom used, because, as has been explained, the calcium ion is of comparatively little service in therapeutics. It has a strong attraction for water and is readily dissociable and is therefore more irritant than the other chlorides of the alkalies and alkaline earths; it ought to be prescribed only in dilute solution, and should not be injected into the subcutaneous tissues or muscle, as it causes great pain and sometimes even sloughing. Instead of the chloride, the lactate has been employed in the same doses and has the advantage of dissociating more slowly and thus causing less pain and irritation when it is injected.

Calx (U. S. P., B. P.) (CaO), unslaked lime, is a corrosive and disinfectant, and is changed at once to the hydrate in the presence of water. It differs from the caustic alkalies in the insolubility of its hydrate, which therefore fails to penetrate deeply and does not spread so widely as potassium and sodium hydrates. It is seldom employed alone as a corrosive, but mixed with potassium hydrate as Vienna paste has had some popularity.

It is used as a disinfectant where large quantities of organic matter have to be rendered harmless, as in epidemics, on battle fields, and in the dejections of large hospitals. It ought to be mixed with the matter to be disinfected as thoroughly as possible. Lime possesses the advantage over other disinfectants of being cheap and easily procurable in large quantities.

Calcii Hydras (B. P.), slaked lime ($Ca(HO)_2$), may also be used as a disinfectant.

Liquor Calcis (U. S. P., B. P.), lime water, is a saturated solution of calcium hydrate or slaked lime and contains about 0.1–0.17 per cent. It is a clear fluid with a saline and feebly caustic taste. 15 mils (4 fl. drs.); B. P., 1–4 fl. oz.

Liquor Calcis Saccharatus (B. P.), syrup of lime, contains calcium hydrate kept in solution in water by sugar, with which it is probably combined chemically 15–60 mins.

Linimentum Calcis (U. S. P., B. P.), lime liniment, or Carron oil, contains equal parts of lime water and olive or linseed oil.

[1] The treatment of hæmorrhage by preparations of tissue juice and serum seems to be more promising and the blood in hæmophilia certainly clots more quickly when tissue juice is added to it in a test-tube. Further experimental and clinical observation is required however before the value of this method can be estimated.

The preparations of the oxide and hydrate owe their activity chiefly to their alkalinity and not to the calcium, but differ from the hydrates of the alkalies in their insolubility and in their slow absorption. Lime water and the syrup are slightly caustic, more especially the latter and tend to neutralize the gastric juice. They have an astringent effect in the intestine which is probably due to their forming an insoluble compound with the surface proteins, in the same way as tannic acid. Lime water is used in some dyspeptic conditions, especially in vomiting. It is often added to milk in intestinal irritation in children and in typhoid fever, as it is said that milk thus treated coagulates in finer particles than when given alone, and is better digested and less liable to disturb the intestine. Lime water or syrup of lime is also used as an intestinal astringent in diarrhœa, especially in children. As an antacid in the stomach, lime is inferior to magnesia and other alkalies, because it tends to delay the evacuation of the contents. It has also been sprayed against the false membrane of diphtheria, which it is said to dissolve. Lime water is not applicable in cases of acid poisoning, as it contains much too little of the base to be serviceable, but the syrup may be used, or lime shaken up with water (milk of lime). The treatment with lime is specially indicated in cases of oxalate poisoning.

Lime water has been used externally as a protective, mildly astringent application to ulcers, and the lime liniment has been largely used in the treatment of burns. It derives its name of Carron oil from having been used for this purpose in the iron works at Carron.

Creta Præparata (U. S. P., B. P.), prepared chalk, chalk purified by washing and suspension in water ($CaCO_3$). 1 G. (15 grs.); B. P., 15–60 grs.

Pulvis Cretæ Compositus (U. S. P.), a mixture of prepared chalk, sugar and acacia. 2 G. (30 grs.).

Pulvis Cretæ Aromaticus (B. P.), aromatic chalk powder, contains chalk along with sugar and a number of carminatives belonging to the group of volatile oils. 10–60 grs.

Pulvis Cretæ Aromaticus Cum Opio (B. P.) is a mixture of 39 parts of the aromatic powder with one of opium, and therefore contains $2\frac{1}{2}$ per cent. of opium. 10–40 grs.

Mistura Cretæ (U. S. P.), chalk mixture, is chalk suspended in cinnamon water by means of gums. 15 mils. (4 fl. drs.)

The preparations of the carbonate of lime are used as antacids in hyperacidity of the stomach, especially when this is combined with a tendency to diarrhœa. The mixture, or the aromatic powder B. P., is the form generally used, and may be prescribed with opium or with other astringents. Chalk has also been used in rickets.

Externally, prepared chalk is used as a powder to protect irritated parts of the skin and occasionally in ulceration; it is the chief ingredient in most tooth powders. In older treatises on therapeutics great virtues are ascribed to various natural objects which are composed for the main part of chalk or other salts of lime, and among which burned bones, coral, coralline and cuttlefish bone may be mentioned.

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XLVIII. OXALATES AND FLUORIDES.

The oxalates (NaOOC—COONa) and the fluorides owe the greater part of their action to their power of precipitating the calcium of the tissues, though they may also cause other effects; this precipitation renders them poisonous to most forms of living matter, of which lime is generally an essential constituent. The oxalate action may be removed in many instances by adding lime salts in excess.

In the frog they cause depression and final paralysis of the central nervous system, and later of the terminations of the peripheral nerves and the muscles and heart; twitching and fibrillary contractions of the voluntary muscles are often observed first.

In mammals there is apparently at first a stimulation of the medullary centres, for rapid, deep breathing occurs in the rabbit, and vomiting and nausea in the dog, and according to some observers, the arterial tension is first increased through stimulation of the vasomotor centre. Later the movements are wanting in coördination, the respiration becomes slow and dyspnœic, the heart is weak, and the animal becomes comatose and dies, sometimes in convulsions.

In cases of oxalate poisoning in man, the early symptoms are great muscular weakness, twitching of the muscles, especially of those of the face, more rarely convulsions; later there follows collapse with a weak, fluttering pulse, pallor or cyanosis, coma and death.

Oxalates are very poisonous to all forms of animal life and to plants containing chlorophyll, but are harmless to the moulds, bacteria and some algæ. The fluorides are equally poisonous to the higher organisms, and in addition have considerable antiseptic power, 1 part in 200 of water being sufficient to arrest the growth of bacteria. Both are absorbed with great difficulty from the stomach and intestine, and cause irritation and effusion of liquid except in very dilute solutions. Added to the blood outside or inside the body, they prevent its coagulation, and the rennet ferment also fails to coagulate milk in the presence of small quantities of oxalate. The frog's heart is much weakened by the addition of oxalate of sodium to the blood perfused through it, while the mammalian heart is not affected by very small quantities, but if the injection of oxalate be continued, becomes suddenly weaker. According to some observers, the terminations of the autonomic nerves are rendered more excitable under oxalates, and this manifests itself in salivation, ready dilation of the pupil, variations in the rate of the heart, and in an abnormal sensitiveness to adrenaline and pilocarpine (Chiari and Fröhlich).

When the ordinary nerve-muscle preparation is soaked in oxalate or fluoride solution, the same twitching and tremor of the muscle is observed as when the salt is injected into the frog. Later the nerve ends are paralyzed, and the nerve fibres lose their irritability, as is indicated by the disappearance of the electrical current of action. The fluorides are powerful local irritants, small quantities applied to the conjunctiva causing congestion and inflammation. Both fluorides and oxalates irritate the stomach and induce nausea and vomiting. This irritation of the alimentary tract may perhaps explain the retarded growth and loss of appetite in rats treated with fluorides (Sollmann).

The fluorides absorbed from the alimentary canal are excreted by the urine, but this takes place very slowly, and much of the fluoride is stored up in the body, some in the liver and skin, but most in the bones in the form of calcium fluoride. Crystals of this very insoluble salt are found in masses in the Haversian canals, and increase the hardness and brittleness of the bones.

Practically the whole of the oxalate ingested is excreted in the urine in the form of oxalate of calcium, and the insoluble crystals are often deposited along the urinary tubules and may stop them up entirely and thus cause anuria, congestion, and inflammation of the kidney; albuminuria is often the most marked symptom in slight poisoning in man. The deposits of oxalates often form white lines running from the base to the apex of the renal pyramids, which are quite evident macroscopically at the autopsy. Small oxalate calculi have also been produced in the pelvis of the kidney, bladder, or ureter through the prolonged administration of oxalate to animals. Not infrequently these renal changes are the only lesions found post-mortem in cases of poisoning with oxalates.

The prolonged administration of oxalates to animals has been found to induce changes in the skeleton identical with those arising from lime starvation; for example, sheep fed on plants containing much oxalate are found to have less lime in the bones than usual.

The other members of the oxalate series, malonates ($CH_2(COONa)_2$) and succinates ($(CH_2)_2(COONa)_2$), differ from the oxalates in being much less poisonous, the fatal dose of malonate of soda being about twenty times that of the oxalate, and the succinate being almost indifferent. The malonate is almost completely oxidized in the tissues, and succinate disappears completely. It is significant that malonic and succinic acids form much more soluble salts with lime than does oxalic acid. Both malonate and succinate of sodium are absorbed only slowly from the intestine, and act as saline cathartics.

Hydrofluoric acid is an exceedingly powerful caustic, destroying the mucous membranes wherever it comes in contact with them. It has been observed that workers in certain departments of glass factories, in which the atmosphere contains a small amount of this acid, are very seldom attacked by tuberculosis, and an attempt has been made to treat pulmonary phthisis by the inhalation of very dilute vapors. The results have not been successful, although there is no question that hydrofluoric acid is a powerful germicide.

Sodium fluorosilicate ($SiFlNa_2$) has also been used as an antiseptic in solution. It has been found to cause nausea, eructation, and slowness of the pulse when swallowed.

The oxalates are not used in therapeutics. In cases of oxalate poisoning the natural antidote is lime, which forms an insoluble precipitate in the stomach and may also relieve the symptoms induced by the withdrawal of lime from its normal combination in the tissues. At the same time large quantities of water and diuretics may be given in order to wash out the crystals of oxalate from the urinary tubules. Oxalate poisoning has sometimes occurred in man from the use of vegetables containing much oxalic acid, *e. g.*, rhubarb leaves.

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(See Calcium.)

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XLIX. BARIUM, STRONTIUM, AND MAGNESIUM.

Barium is the most poisonous of the alkaline earths, but resembles the others in penetrating with difficulty into the epithelium of the alimentary canal, and is therefore absorbed very slowly. It has a characteristic action on many forms of muscular tissue, resembling closely that of veratrine, and the contraction of the frog's muscle under barium is thus stronger than normally, and is greatly prolonged; this action is not opposed by curara and is therefore believed to be exerted on the contractile substance directly. The frog's heart beats more strongly, but more slowly from a similar action on the muscle fibres, and the walls of the stomach and intestine are thrown into violent contraction from the action of the metal on the unstriated muscle fibre. There is some question as to whether the central nervous system is acted on in the frog, but in the mammal barium salts injected intravenously cause violent tonic and clonic spasms, from their stimulating the spinal cord and medulla oblongata. The action on the alimentary canal induces vomiting and purging with very active peristalsis. The heart is accelerated and the blood-pressure is enormously increased at first, and then undergoes slow undulations for some time. The increased tension may be due to the cardiac action in part, but is chiefly to be ascribed to a very marked contraction of the muscular walls of the vessels. The frog's heart eventually assumes an irregular peristaltic form of contraction and ceases in systole, as in digitalis poisoning, and the changes in the mammalian heart also resemble those caused by this series. Barium in sufficient quantities finally paralyzes the central nervous system. In fatal poisoning in animals hæmorrhages have been found in the stomach, intestine, kidney, and other organs.

Barium is quite incapable of replacing calcium in its relations to living matter, and accordingly chloride of sodium solutions to which barium chloride has been added do not tend to keep the frog's heart active as do those containing lime. Some authors hold that barium can replace calcium to an imperfect degree in the coagulation of the blood, but this is denied by others. Potassium salts tend to neutralize the effect of barium on the heart and muscles, the relation resembling that which they bear to lime.

Barium is absorbed slowly from the intestine and is found to be stored in the bones to some extent, and to be excreted by the intestinal epithelium, only traces appearing in the urine.

It has been suggested as a substitute for digitalis, but has seldom been used in practical therapeutics. In veterinary practice it is often employed as a purgative.

Strontium is a comparatively inert substance even when injected directly into the blood, resembling calcium in its action in the body as far as is known, but being even less poisonous. It contracts the muscles somewhat, tends to lessen the dilatation of the heart, and prolongs the contraction of muscle, though only to a slight extent. It has not the antagonistic effects to magnesium which are possessed by calcium, nor, on the other hand, does the last named prevent the symptoms induced by large quantities of strontium. It is absorbed very

slowly from the intestine like the other alkaline earths, and is deposited in small quantities in the bones of growing animals, especially when there is a deficiency of lime in the food; but it cannot be used to replace the calcium of the food, animals treated thus showing the symptoms of lime starvation. It is excreted in small quantities by the urine, but mainly by the bowel. Strontium salts have been used to a limited extent in therapeutics, not for the effect of the strontium ion, but for the bromide, iodide or salicylate anions. They possess no advantage over the corresponding salts of potassium and sodium.

The **Magnesium Salts** have recently been shown by Meltzer to have a very powerful action when injected hypodermically or intravenously. The most characteristic effect is complete anæsthesia, resembling that induced by the chloroform group, and ending in fatal cases in paralysis of the respiratory centre. This arises from direct affection of the central nervous system, and immediate recovery follows the injection of a calcium salt, which opposes the magnesium action in the same way as it does that of sodium (see Calcium). The magnesium anæsthesia does not appear to arise from its penetrating into the brain cells, for no significant amount can be obtained by analysis, while large quantities are found in the plasma; the action of magnesium is thus an enigma to which the key has yet to be found. Applied to a nerve trunk, magnesium salts in 25 per cent. solution act in the same way as cocaine, paralyzing first the afferent and later the efferent fibres, and injected into the intradural space they cause complete anæsthesia of the lower part of the body like cocaine; magnesium sulphate has, in fact, been substituted for cocaine occasionally for surgical operations and in the treatment of tetanus. The anæsthesia lasts much longer and this renders it unsuitable for surgical work, but several cases of tetanus treated by subdural injection of magnesium sulphate have recovered. (Dose, about 0.02 G. per kg. in man.) The same anæsthetizing action is seen in the lower invertebrates when a magnesium salt is added to the water in which they live. Magnesium has comparatively little effect on the heart, tending to lessen the excitability of the vagus, and this effect may also be abolished by lime salts. It reduces the irritability of the intestine when injected intravenously and arrests the peristalsis aroused by physostigmine or barium. It also appears to have some effect on the myoneural receptors in muscle, for it arrests the twitchings induced by physostigmine and in large doses interrupts the path from nerve to muscle in the same way as curara. When injected intravenously magnesium proves to be considerably more poisonous than potassium, but, unlike the latter, kills by paralyzing the respiration. None of these effects are elicited when magnesium salts are given by the mouth, as that absorbed is excreted rapidly and there is never enough accumulated in the blood to have any action. Magnesium is excreted by the kidney and traces may appear in the secretions from other organs. It is eliminated rapidly, almost the whole appearing in the urine within forty-eight hours, and this excretion of magnesium is attended by an increase in the calcium of the urine, while that of the fæces may diminish.

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L. SULPHIDES.

The ordinary sulphides of the alkalies are of little importance in themselves, as they are seldom used in therapeutics. The effect of hydrosulphuric acid,

however, apart from its local irritant action, is due to the sulphide which it forms in the blood, and the study of this powerful poison therefore involves a preliminary examination of the effects of the sulphides. Again, sulphur is in itself inert, but is changed to sulphides and hydrosulphuric acid in the alimentary canal, and the effects induced by its administration are due to these bodies, and not to the original element (p. 94).

Action.—The sulphides are very weak salts, for even carbonic acid is capable of liberating hydrosulphuric acid, and wherever they come in contact with it in quantity there is a tendency to form free acid, which acts as a powerful local irritant; it is not impossible that the sulphides have an irritant effect of themselves in addition to that of the hydrosulphuric acid The sulphides accordingly act as irritants in the stomach and bowel, and in the latter induce increased peristalsis and purgation. When injected subcutaneously in the frog, sodium sulphide causes a narcotic condition from depression of the central nervous system, and in sufficient quantities weakens the skeletal muscle and the heart, which continues to beat after complete paralysis has been obtained, but eventually ceases in diastole. After the narcosis has lasted for some time, there follows a marked increase in the reflex irritability, with convulsions resembling those of strychnine poisoning in their general character, but differing from them in lasting continuously for weeks or even months at a time. The animal lies in an extended and tense condition throughout, and passes into complete opisthotonos on being touched.

Sulphides injected intravenously in mammals induce violent convulsions, which seem to be of cerebral origin, for they do not occur in the hind limbs when the spinal cord is cut. The respiration is at first accelerated and later dyspnœic and finally ceases, this, along with the paralysis of the vasomotor centre, being the cause of death. The heart does not seem to be seriously affected except indirectly through the failure of the respiration and the fall of the blood-pressure.

Sulphide solutions added to drawn blood reduce the oxyhæmoglobin at once, and give the blood a dark venous color. At the same time a compound of sulphide and hæmoglobin is formed, the chemistry of which is still very obscure, but which would seem to be more nearly related to methæmoglobin than to hæmoglobin. It is known as sulpho-hæmoglobin or as sulpho-methæmoglobin, and gives the blood a greenish color when a thin layer is examined, while a thicker layer is dark red-brown. This sulpho-hæmoglobin possesses a characteristic spectrum, marked by a dark line in the red to the left of the D line. Larger quantities give an olive-green color to the blood, and the spectrum of sulpho-hæmoglobin disappears. When sulphides are injected into frogs, and more especially when sulphuretted hydrogen is inhaled, the blood gives the characteristic spectrum during life, but this does not seem to be the case in mammals, although sulpho-hæmoglobin is formed soon after death. The blood changes are not the cause of death in poisoning, as was formerly supposed, but the direct action of the sulphides on the central nervous system.

Sulphides absorbed into the blood are rapidly oxidized, and are excreted in the urine in the form of sulphates and of organic sulphur compounds of unknown constitution. Small quantities escape by the lungs, and give the breath the disagreeable odor of sulphuretted hydrogen, and some is excreted in this form in the perspiration.

The sulphides dissolve the horny epidermis and hair very readily when they are applied to the skin. If the application is continued, some irritation and redness is produced.

Hydrosulphuric Acid (sulphuretted hydrogen, hydrogen sulphide (H_2S)) is a gas with strong irritant properties, which it shares with other acids (see page 556) and has not infrequently given rise to poisoning, as it is formed in large quantities in the course of the putrefaction of sulphur compounds, such as proteins. Sewer gas often contains it in quantity, and workmen employed in cleansing sewers or cesspools have often suffered from its effects. When inhaled

in concentrated form it is almost immediately fatal, the patient losing consciousness at once, and the respiration ceasing after a few seconds. In smaller quantities it causes immediate unconsciousness, lasting for several hours and then passing into fatal coma, which is often interrupted by violent convulsions. In both of these forms the symptoms are due to the direct action of the sulphides on the brain and medulla oblongata. Persons exposed to a very dilute vapor of sulphuretted hydrogen suffer from local irritation of the eyes, nose and throat, indicated by pain and congestion of the conjunctiva, sneezing, dryness and soreness of the mouth and throat, and a reflex increase in the secretion of tears, saliva, and mucus. Headache, dulness, giddiness and loss of energy are complained of; the symptoms frequently appear only some time after the exposure to the poison. Death in animals exposed to these dilute fumes is due in part to œdema of the lungs caused by the local irritant action. One part of hydrosulphuric acid in 5,000 of air is sufficient to induce symptoms in man, and an atmosphere containing one part in 2,000 can be respired for only a short time, and gives rise to alarming symptoms; about one part of hydrosulphuric acid in 1,000 parts of air is sufficient to poison a man fatally in ten minutes.

The poisonous effect of sulphuretted hydrogen is due in part to its local irritant action, in part to its directly affecting the central nervous system. The changes in the blood occur during life only after very concentrated gas is inhaled, although they may indicate the poison after death from more dilute vapor, for the tissues in general tend to assume a green color sooner after hydrosulphuric acid poisoning than in the course of ordinary putrefaction.

Hydrogen sulphide is destructive to most forms of life, even when present in comparatively small amount. The microbes of putrefaction, which produce it themselves, are eventually killed by this gas, unless it escapes freely.

Preparations.

Potassa Sulphurata (U. S. P., B. P.), liver of sulphur (Hepar Sulphuris), is a mixture of polysulphides and thiosulphides, often containing sulphate of potassium. It is soluble in water and possesses an unpleasant saline taste, and an odor of hydrogen sulphide.

Calx Sulphurata (B. P.) *Calcii Sulphidum Crudum* (U. S. P.), sulphurated lime, is another impure preparation containing at least 55 per cent. of calcium monosulphide (CaS) with some calcium sulphate and charcoal. It forms a grayish powder, insoluble in water, and gives off hydrogen sulphide.

Sulphurated potassium is used to a very limited extent as an external application in certain skin diseases, particularly in acne, and to destroy skin parasites, such as that of scabies. It is used as an ointment (1 part to 10 parts), and is somewhat irritant.

Sulphurated lime is used occasionally to remove hair and horny excrescences, both of which it renders soft and gelatinous, but its frequent use is liable to cause irritation.

Many mineral springs contain hydrogen sulphide in small amount, and these have obtained wide celebrity in the treatment of various chronic respiratory and skin diseases and in syphilis, gout, rheumatism, and chronic metallic poisoning (lead, mercury). Most of these springs are hot, and it is open to question whether the small amount of the gas contained in the water is of any efficacy, and whether the heat of the water and the hygienic conditions are not the true cause of the improvement observed in these cases. Sulphur baths are also formed artificially by the addition of sulphurated potassium (2–8 oz.) to an ordinary hot bath; a small quantity of acid is sometimes added, in order to free the hydrogen sulphide more rapidly.

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LI. CHARCOAL.

Charcoal, like spongy platinum and other porous bodies, possesses the property of adsorbing gases in its interstices and thus ordinarily contains considerable quantities of oxygen. When brought into contact with decomposing matter, the oxygen is released and hastens the oxidation of the putrefying mass, while the gases arising from the bacterial action are adsorbed by the charcoal, which thus acts as a deodorant. It has no direct action on the microbes of putrefaction, but may by introducing oxygen favor the development of the aërobic organisms at the expense of the anaërobic. Besides gases, charcoal also adsorbs many organic bodies, such as the coloring matter of plants, proteins and alkaloids.

Different samples of wood charcoal vary in their power of adsorption, those prepared from hard woods being generally more efficient; animal charcoal has no advantage over the vegetable preparations. Charcoal acts when moist as well as in the dry state.

Charcoal has no appreciable effect on the economy, apart from its lessening the eructations of gas and the flatulence in some cases. It passes through the stomach and intestine unabsorbed, and may in rare cases cause some mechanical irritation and increased movement. Charcoal given in a state of suspension to animals is said to have been found in the epithelial cells of the intestine and even in the bloodvessels, but does not have any effect attributable to its absorption in man. (*Wild.* Med. Chronicle, 1896).

Carbo Ligni (U. S. P., B. P.), charcoal prepared from soft wood and finely powdered. Dose, 1 G. (15 grs.).

Charcoal is used internally to remove the gases in flatulence and dyspepsia, and is prescribed in powder or in the form of charcoal lozenges. It may be given in any quantity, but is most commonly prescribed in 4–8 G. (60–120 grs.) doses. It has been advocated in poisoning with alkaloids and other vegetable poisons to take these up in the stomach and delay their absorption into the blood. It is employed externally as a deodorant in cases of foul ulcers, cancerous sores, or malodorous secretions from any source; for this purpose it is added to poultices or used dry in bags of fine cloth.

LII. CARBONIC ACID.

Carbonic acid is contained in considerable quantity in many therapeutic preparations, notably in the effervescent cathartics and antacids, and also in many beverages, such as soda water, potash water, champagne, and other sparkling wines. In some of these it is formed by the action of an acid such as citric or tartaric acid on carbonates, in others it is liberated in the course of fermentation, while in the artificial aërated waters it is forced into solution under high pressure. The last are therefore simple solutions of carbonic acid, while in the others more powerful agencies—cathartic salts or alcohol—are contained in addition.

Carbonic acid has a weak irritating action when applied in quantity; thus in baths charged with carbonic acid, a slight reddening of the skin has been observed, and some irritation and prickling of denuded

surfaces is produced; a stream of carbonic acid directed against a wound or burn causes considerable heat and pain. Pure carbonic acid gas causes spasm of the glottis when inhaled, and even when it is much diluted, some irritation in the respiratory passages may follow at first. Solutions of carbonic acid induce reddening of the mucous membrane of the mouth and stomach, and are very rapidly absorbed, owing to the congestion and increased blood flow in the stomach wall which follows their administration. Much of the carbonic acid is thrown up by eructation, but some of it is absorbed and is excreted by the lungs. The absorbed acid has no effect on the organism, but the slight irritation of the stomach may cause increased appetite and a feeling of well-being. The rapid absorption of the water in which it is dissolved is followed by an augmented secretion of urine, and the carbonic acid waters are therefore used in preference to ordinary waters where a rapid flushing of the tissues and a profuse secretion of urine is desired. In addition, the slight irritation of the mouth and stomach renders them more acceptable than ordinary waters in fever and in other diseases accompanied by intense thirst; a mixture of milk and aërated water is often very grateful. The presence of carbonic acid in the sparkling wines leads to the rapid absorption of the alcohol also, and this action on the stomach may explain their being more exhilarating than other wines containing an equal amount of alcohol. The slight irritant effect of carbonic acid in the stomach has proved of benefit in some forms of gastric catarrh, such as that following alcoholic excess. Carbonic acid waters are also useful in the vomiting of pregnancy and in seasickness.

The prolonged application of carbonic acid to the mucous membranes leads to local anæsthesia, and numbing of the skin is also stated to occur under similar treatment.

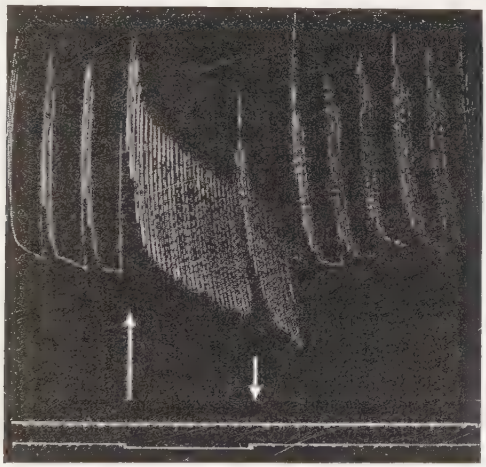
Carbonic acid is absorbed from all the mucous membranes, from the skin and from the lungs. The gas has no effect after absorption except when inhaled, however, as when absorbed in any other way it is at once excreted by the lungs, and the amount absorbed never alters appreciably the normal percentage of carbonic acid in the blood.

When carbonic acid is inhaled unmixed with oxygen, it induces asphyxia, partly from a specific action which it exerts on the central nervous system, but chiefly from the absence of oxygen. Its effects are, therefore, very similar to those of any indifferent gas, such as hydrogen or nitrogen, and the symptoms are those of ordinary asphyxia. When, however, carbonic acid is inhaled mixed with a sufficient amount of oxygen, the specific effects of the gas are observed without any asphyxia. The symptoms are those of transient stimulation and subsequent depression of the central nervous system and heart. The first stage is marked by a very short period of psychical exaltation, with deep respirations, a slight rise in the blood-pressure and a moderately slow pulse. Very soon, however, unconsciousness, loss of the spontaneous movements, and later of the spinal reflexes follow, the respiration becomes somewhat slower and shallower, the pulse continues slow and the heart is weaker. If the inhalation be continued the respiration fails, the heart continuing to beat for a short time, though weakly. The symptoms of the first stage seem to be due to a direct stimulant action on the cerebrum and on the vagus, vasomotor and respiratory centres, while the second stage resembles that induced by the ordinary anæs-

thetics, and is evidently caused by depression of the central nervous system and of the heart muscle. In fact a mixture of carbonic acid and air has been used as an anæsthetic in one or two surgical operations. Death from carbonic acid poisoning is not preceded by convulsions, those observed in ordinary asphyxia being due to the absence of oxygen, and not to the excess of carbonic acid; it is still undecided by which of these factors the increased peristalsis seen in suffocation is caused. In well diluted vapor the symptoms of exaltation alone are observed, no anæsthesia following. A mixture of 5 per cent. carbonic acid in air causes acceleration and deepening of the respiration without further changes.

Carbonic acid in excess acts as a poison to other organs besides the central nervous system and the heart, although this effect is not seen in mammals. Frog's muscle loses its irritability rapidly, the ciliated epithelium ceases movement and the motor nerves, after a short period of increased excitability, are paralyzed by exposure to an atmosphere of carbonic acid. The blood assumes the venous color when shaken with the gas, and prolonged contact produces

FIG. 71



Periodic respiration in a rabbit. Between the arrows, 6 per cent. CO_2 in air was inhaled and the respiration became regular, but relapsed again soon afterwards.

acid hæmatin, as does any other acid. It is a general poison to the protoplasm in mammals, apart from the effects on the central nervous system, for the combustion in the tissues is lessened to an extraordinary degree, as is evidenced by the very small amount of oxygen absorbed

Carbonic acid is the natural stimulus of the respiratory centre, and it has been suggested as a remedy in some forms of respiratory failure; thus in opium poisoning it would seem a rational form of treatment to inhale 5–7 per cent. of carbonic acid in air. In some forms of Cheyne-Stokes respiration it has been found that dilute carbonic acid restores regular breathing (Fig. 71).

Mineral waters containing large quantities of carbonic acid in solution are often recommended as baths in various chronic diseases, such as rheumatism. The effects may be due to the carbonic acid in part, but these waters also contain salts in solution.

Solid carbonic acid (carbonic acid snow) has been applied as an irritant in various external conditions (page 83) and has also been used to induce local anæsthesia by cold (page 74).

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LIII. OXYGEN.

Ever since the discovery of the relation of oxygen to the respiration, attempts have been made to use it in therapeutics, by inhaling the gas pure or mixed with air, or by spending a certain time each day in chambers of compressed air. It was expected that by these means a larger amount of oxygen would be absorbed, and a more active combustion in the tissues would be induced. The oxygen is carried to the tissues for the most part in the form of oxyhæmoglobin, a very small fraction existing in simple solution in the plasma. Now in normal conditions the air inhaled by the lungs suffices to saturate about 95 per cent. of the hæmoglobin in the pulmonary vessels and the breathing of pure oxygen can increase only by 5 per cent. the amount carried as oxyhæmoglobin. It is true that the oxygen dissolved in the plasma is increased by inhaling pure oxygen, but this dissolved oxygen is trifling in amount compared with that in combination with the hæmoglobin. As far as the tissues are concerned, the oxidation is of course the same whether the oxyhæmoglobin carried to them by the blood was formed in a pure atmosphere of oxygen or in air, of which it comprises only about 20 per cent. The slight increase in the oxyhæmoglobin of the blood has no appreciable effect, as more oxygen is offered to the tissues normally than they can assimilate. It is therefore inconceivable that the very slight increase in the quantity of oxygen in the blood can have any effect on the oxidation in the tissues under ordinary conditions. But if the gas be inhaled in high concentration, the augmented tension in the blood may induce some symptoms, and this is, according to Smith, the explanation of a tendency to tetanic convulsions which he found developed in animals under these circumstances; hilarity and some other nervous effects are said to have been induced in man in some instances, and these may also be interpreted as the results of the high oxygen tension in the blood, if they were not the products of fancy and suggestion. Oxygen inhalation is therefore incapable of increasing the oxidation in the tissues, or in fact of modifying in any way the metabolism, and experience has shown it to be valueless in such constitutional diseases as diabetes and gout, in which, moreover, it has been demonstrated that there is no deficiency in the oxygen of the blood.

The further question arises whether oxygen inhalation is likely to be of benefit in the cyanosis due to severe cardiac or pulmonary disease. Improvement is often observed clinically, the skin losing its dark color, and the respiration and heart becoming less rapid and labored as soon

as the inhalation is commenced, and alarming symptoms returning when it is stopped. This has been explained by the larger amount of oxygen dissolved in the plasma; when air is breathed, the plasma contains only about 0.35 per cent. of oxygen in simple solution, but when oxygen is inhaled the content may rise to 3 per cent. and this may reinforce the oxygen carried by the hæmoglobin. In cases in which only a small quantity of blood is passed through the lungs owing to circulatory disorder, this small supplementary supply of oxygen may be of importance. Again when the aërating surface of the lungs is covered with exudate, through which oxygen penetrates with difficulty to the absorbing membrane, an increased partial pressure of oxygen in the alveoli accelerates the rate of passage, wherever the surface is covered with excessive moisture, as in failure of the circulation, after the inhalation of irritant gases, or often in pulmonary disease, increased aëration of the blood may be expected from oxygen inhalation.

Further it must be remembered that the air actually inspired does not pass directly into the alveoli, but diffuses from the wider air passages into the narrower ones and then reaches the absorbent surfaces. Pure oxygen diffuses more rapidly and in larger quantity into the alveoli than when it is mixed with nitrogen, and when the movement of the air in the air passages is insufficient, oxygen may give relief by diffusing in larger quantity into the alveoli. Insufficient movement of the air currents may be due to obstruction of the respiratory tract, as in asthma or severe bronchitis or pneumonia, or to shallow breathing. Hill and Twort state that when the breathing is deep in normal persons, the oxygen in the blood is not altered when oxygen is inhaled instead of air, but that when the breathing is very shallow, much more oxygen is contained in the blood during oxygen inhalation. The same increase may occur when the breathing is insufficient through exudation. Many observers have noted that the pulse is slowed by the inhalation of oxygen, even when there is no increase in the oxygen absorbed or in the carbonic acid exhaled, and the statement is made that greater exertion is possible under oxygen breathing than under air.

When the hæmoglobin of the blood is so altered as to be incapable of transporting oxygen to the tissues, as in cases of poisoning with carbon monoxide, nitrites, chlorates, nitrobenzol, etc., oxygen inhalation is indicated, for it has been shown by Haldane and others that the plasma dissolves enough oxygen to maintain life when that supplied by the blood corpuscles is insufficient. The inhalation has to be continued until the symptoms of deficient aëration have disappeared.

Many microbes are killed or at any rate much retarded in their growth when freely exposed to the air, and attempts have been made to treat pulmonary phthisis by oxygen inhalation. The results have been less disastrous than those of some of the other treatments by inhalation, but no distinct benefit has accrued, and in some cases hæmoptysis has been induced by it from some unexplained cause. Smith has found that the inhalation of oxygen under some pressure causes irritation, congestion and consolidation of the lungs in mice and birds.

Oxygen is supplied under pressure in large cylinders. It is sometimes inhaled through a mask connected with a bag filled from the container, but the mask often gives a sense of suffocation and is rejected by the patient. Others supply it from a funnel held above the face, but the amount which reaches the lungs by this means is insignificant. The ideal method involves the use of an air-tight chamber in which the patient is placed; oxygen is admitted to the required amount while the CO_2 is removed by alkali. Where such a chamber is not available, the oxygen may be given through a soft tube passed into a nostril or into the mouth and good results are obtained in this way. The inhalation is continued until the cyanosis disappears, and has to be renewed when it returns.

Ozone, or active oxygen (O_3), is a much more powerful oxidizing body than ordinary oxygen, but is more easily reduced than peroxide of hydrogen. It has a curious phosphorous odor and is distinctly irritant to the respiratory membranes; it is almost always accompanied by nitrogen oxides, and these may further aggravate this local irritation. It is rapidly decomposed by living matter, and is certainly not absorbed into the blood unchanged; in fact it is immediately destroyed on the pulmonary surfaces. In man its inhalation in a dilution of 2–3 per million of air causes drowsiness and headache from irritation of the frontal sinus. In animals 15–20 parts of ozone per million of air sometimes proves fatal in a few hours from respiratory irritation; a condition of weakness and drowsiness precedes death, apparently as a result of the local irritation, and the lessened movement is accompanied by a fall in the CO_2 eliminated. Ozone injures most enzymes and the fermentation of yeast is hindered, but the lactic fermentation does not seem to be affected and some others are merely delayed. Ozone applied to the seeds or leaves of the higher plants also delays their development and injures them.

Ozone has undoubtedly disinfectant properties, but these are only apparent when air contains 15 mg. or more per litre. Even this disinfects only the air itself and the surfaces of objects, as the ozone loses its oxidizing properties whenever it comes in contact with organic matter and therefore fails to penetrate. It has recently been advocated to disinfect drinking water, but is efficient only in fairly pure waters, as any organic matter is oxidized and thus absorbs the ozone and the microbes escape. For this reason it cannot be used to sterilize milk or food. Comparatively low dilutions are sufficient to lessen the perception of odors, partly owing to the smell of ozone itself and partly by its action on the nasal mucous membrane.

Ozone inhalation has been recommended as an antiseptic in pulmonary phthisis, but its irritant properties preclude its use here, and it has been generally discarded. It was supposed to be formed in turpentine oil on standing, and old turpentine oil was therefore recommended in cases of phosphorus poisoning, with the hope that it would tend to oxidize the phosphorus and render it harmless. Recent investigations show, however, that no ozone is formed in turpentine oil, and there is no reason to suppose that the treatment is of benefit.

Ozone is of no value as a substitute for oxygen, and this applies equally to other oxidizing agents; oxygen must be supplied in the molecular form to combine with hæmoglobin.

Many so-called solutions of ozone contain only small percentages of hydrogen peroxide and no ozone proper, as, though the latter is soluble in water, it decomposes very rapidly, only traces of it being found in the solution after ten to fifteen days. It breaks up into oxygen, and does not form hydrogen peroxide.

The ozone of the air has been appealed to, in order to explain and advertise the benefits induced by many watering places and forest resorts, but it has never been satisfactorily proved that the air in these localities contains more ozone than in other less favored places. The curative agency is generally the change of scene and interests and the dietary.

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LIV. PHOSPHORUS.

In the early part of last century phosphorus played a very important role in therapeutics, and, in fact, was regarded almost as a panacea, but at present its use is much more restricted, and doubt is entertained as to its possessing any therapeutic value whatever. At the same time, it has been the subject of much and laborious investigation, partly because it has frequently given rise to poisoning, and partly because the study of its effects has thrown much light on some physiological and pathological processes. It differs from most poisons in acting for the most part on certain phases of the animal metabolism, and it is believed that the liver is the chief seat of its activity.

Phosphorus is absorbed with difficulty, because it is very insoluble in water and the body fluids and is only slowly volatilized at ordinary body temperature. Large masses of phosphorus may thus pass through the alimentary canal without serious effects, because they fail to be dissolved and absorbed. But when it is taken in a finely divided condition or in solution in oil, it gives rise to symptoms in very small quantity, and has been found to induce fatal poisoning in man in doses of 0.05–0.1 G. (1–2 grs.).[1] In these conditions it is absorbed partly as vapor, partly in solution in water, which dissolves only traces, however, and probably chiefly in solution in the fats and oils, in which it is much more soluble. Phosphorus vapor is also absorbed by the lungs, and the symptoms of chronic poisoning in match factories are believed to arise in this way. It does not seem to be taken up from the skin, and has in fact little effect unless when rubbed on it, when it ignites and gives rise to severe burns; phosphorus burns do not cause phosphorus poisoning, however, as is sometimes stated. The red amorphous phosphorus is much less poisonous than the ordinary yellow form, because it is less soluble and also less volatile, and consequently fails to be absorbed.

Phosphorus exists in the blood as such, and the effects on the tissues are unquestionably due to the element itself, and not to the oxygen or hydrogen compounds, as has been supposed. Some phosphuretted hydrogen (PH_3) may be formed in the bowel, but is comparatively unimportant, the great mass of the phosphorus being absorbed unchanged. As soon as it is oxidized, phosphorus loses its specific action, all of the acids being comparatively harmless. Phosphorus has been detected in the blood, and, it is said, in some of the excretions.

It is devoid of action on albumins in solution and has no immediate irritant effects, such as are seen in poisoning with the heavy metals.

Symptoms. –When a poisonous dose of phosphorus is swallowed, no effects are elicited as a general rule for several hours. The first symptoms are pain and discomfort in the region of the stomach, nausea and eructation of the vapor

[1] Phosphorus is often used in suicide, generally in the form of rat poison or of match heads. Each phosphorus match is estimated to carry 3–5 mg. of phosphorus, so that 15–20 match heads are sufficient to induce fatal poisoning.

with its characteristic garlic odor, and then vomiting, the contents of the stomach having the same odor, and being phosphorescent in the dark. Later, bile may be vomited, and some diarrhœa may set in, although this is not a common symptom. The nausea and vomiting often continue without further symptoms for several days, but frequently disappear, and the patient apparently recovers, particularly if the dose has been small, or if most of it has been removed by vomiting or by washing out the stomach. In the course of a few days, however, the symptoms recur, and are generally accompanied by some jaundice; the pain extends from the stomach to the liver, and soon to the whole of the abdomen. The vomited matter no longer contains phosphorus, but may be bloody. The patient complains of general weakness and faintness; the pulse is weak, the liver extends far below the ribs, and the urine shows characteristic changes (see page 587); hæmorrhages occur from the nose, bowel, uterus and under the skin, and eventually a condition of collapse and fatal coma or delirium and convulsions follow.

Exposure to the fumes of phosphorus has long been known to give rise to periostitis and necrosis of the lower jaw. The disease begins from a carious tooth or from some lesion of the gum, and may involve most of the jaw, which becomes swollen and painful and eventually evacuates large quantities of pus with pieces of dead bone. This necrosis was formerly frequent in match factories, but has become rarer since amorphous phosphorus has been substituted for the yellow form,[1] and since greater attention has been paid to the ventilation of the factories and to the condition of the teeth of the employees. Magitot has recently advanced the opinion that exposure to phosphorus fumes gives rise to a mild chronic form of poisoning, quite aside from the necrosis, which is comparatively rare. The symptoms are cachexia, slight jaundice, anæmia and albuminuria, and in more advanced cases chronic enteritis and diarrhœa, bronchitis and a curious fragility of the bones.

Action: Fatty Infiltration.—A very striking feature in phosphorus poisoning is the appearance of numerous fat globules in the cells of many organs, notably in those of the liver, kidney, gastric and intestinal glands, and in the muscle fibres of the heart, stomach, intestine, smaller arteries, and often of the skeletal muscles. This fat was formerly believed to be formed by the degeneration of the proteins of the cells in which it is found, but it appears that it is really ordinary fat transported from the positions which it normally occupies and deposited in the cells of the liver, heart, and other organs. Pflüger has shown that the total fat of the body is not increased by phosphorus, and Rosenberg found that when an animal has been fed on foreign fats (*e. g.*, a dog upon mutton suet) and is then poisoned with phosphorus, the fat found in the liver cells is that characteristic of the food and not that of the poisoned animal as might be expected if it were derived from the proteins. Further, Leathes has shown that the fat found in the liver in phosphorus poisoning possesses the characteristics of fat ordinarily found in the subcutaneous deposits and not that of the fat of organs, so that there is every reason to regard it as normal preformed fat deposited in unusual positions, rather than as a new product of the intoxication. The fatty infiltration sets in only after some time, and, in fact, accompanies the secondary symptoms for the most part, although the cells of the stomach and upper part of the intestine suffer sooner, and the beginning of this process is probably the cause of the early vomiting. The process commences in cloudy swelling of the cells, followed by the appearance of granules, which soon develop into fat globules. Eventually the degenerated cells break up into detritus.

Another feature in phosphorus poisoning, which is, however, better seen after repeated small doses than after a single large one, is the **Proliferation of the Interstitial Connective Tissue** of the stomach, liver and kidney, which finally

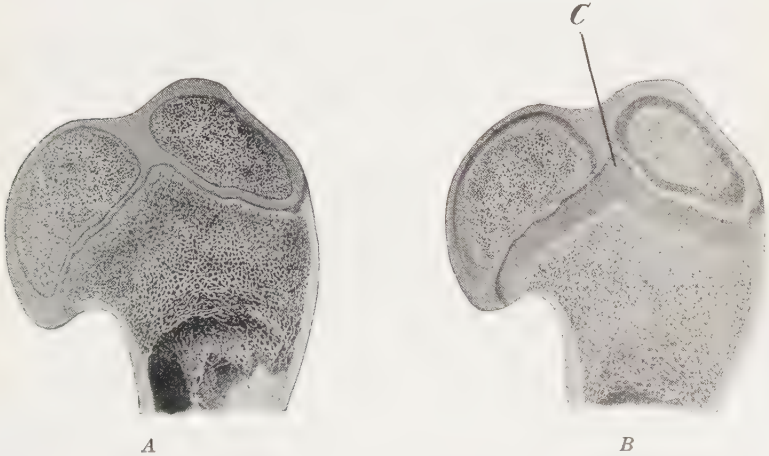
[1] The phosphorus sesquisulphide (P_2S_3), recently introduced in match factories, seems to be even safer than red phosphorus, for though minute quantities of the element are released from it in the tissues, these are too small to induce any symptoms.

induces typical cirrhosis of these organs; it appears to be a secondary result of the necrosis of the parenchyma cells, and may result in dropsy, anæmia, and cachexia in animals.

When very minute quantities of phosphorus are administered to animals, no poisoning results, but according to Wegner, a specific action on the **Bones** is induced, especially in young animals, in which the bones are still growing. Thus, in young rabbits, quantities of $\frac{1}{10}$ $\frac{1}{5}$ mg. given for several weeks are found to cause the deposit of a layer of dense bone at the growing point, while the soft cancellous bone is gradually absorbed.

Kassowitz observed the layer of white dense bone described by Wegner at the edge of the ossifying cartilage, but he regards it not as the result of excessive activity of the osteoblasts, but as due to a slower absorption of the calcified cartilage from a less rapid extension of the bloodvessels than is normal. Several other investigators have observed changes in the bones after phosphorus, so that there is good reason to believe that it possesses some specific action on them, although some writers failed to obtain definite results, and of those who observed a modification in the growth no two agree in the description of the changes or in their interpretation

FIG. 72



Section of the head of the femur in a calf. *A*, normal; *B*, after treatment with minute doses of phosphorus; *C*, the cap of dense bone at the growing point. (After Wegner.)

This specific action on the bone-forming tissues may explain the necrosis of the jaw in match factories. The view of the latest investigators is that microbial infection is necessary to permit of the changes observed clinically, but that phosphorus induces some change in the bones which predisposes them to infection by the tubercle bacillus and other organisms which induce necrosis. The occurrence of necrosis of the jaw is in fact a strong argument for the correctness of the view that a specific action on bone exists, for under no other poison, even when much more irritant vapor is inhaled, does a similar process occur in man. And a further argument for this specific action is the fragility of the bones which occurs in a considerable percentage of workers in match factories. Here the phosphorus is carried to the bones (femur, tibia, radius, etc.) in the blood and there is no possibility of its reaching them directly as in the case of the jaw. It seems probable therefore that in phosphorus necrosis of the jaw the bone is changed by the phosphorus absorbed and carried to it by the blood and that this change predisposes to infection through a diseased tooth or sinus. The exact nature of this action on bone and its relation to rickets and to osteomalacia must, however, be left for further research to determine.

Phosphorus weakens and slows the **Heart** when it is applied to it directly in the frog, or by intravenous injection in mammals. In many cases of acute poisoning in man, however, the heart does not seem to be seriously affected until very late, especially when small quantities have been absorbed; fatty degeneration of the cardiac muscle is seen in the later stages of poisoning.

In many cases of fatal poisoning the **Blood** is found not to clot so readily as usual, and sometimes to remain fluid for forty-eight hours or more; this is not a direct effect of the poison, but is secondary to the changes in the intestine and liver, which lessen or entirely destroy the fibrinogen. The amount of fat in the blood is considerably increased in phosphorus poisoning, owing to the migration of the fats from the usual deposits to the liver.

The absence of clotting in the blood may be a factor in the hæmorrhages which are met with among the symptoms of the second stage, but the immediate cause of these is the fatty degeneration of the muscular coat of the smaller arteries throughout the body. These changes in the bloodvessels may perhaps explain the œdema of the retina and the gangrene of the extremities which is seen in animals poisoned with phosphorus.

The **Bone-marrow** in chronic poisoning is at first hyperæmic, the fat cells are atrophied and the leucoblasts are greatly increased; later a gelatinous degeneration sets in with a decrease in the number of the marrow-cells and a corresponding increase in the connective tissue.

The peripheral **Nerves** and **Muscles** do not seem to be affected in phosphorus poisoning, except in so far as the latter undergo fatty infiltration. An excised muscle lives almost as long in salt solution containing phosphorus as in the unpoisoned solution.

The **Central Nervous System** is also little changed by phosphorus. The coma and convulsions which appear before death may be due rather to the disordered metabolism than to any direct influence, as is shown by the fact that consciousness is preserved throughout the first stage, and as a general rule until late in the second.

The fatty changes in the epithelial cells of the **Stomach and Intestine** explains the abdominal pain, the vomiting and the occasional diarrhœa seen among the secondary symptoms. The earlier phases of this action may be the cause of the vomiting and nausea of the first stage. This degeneration occurs also when phosphorus is injected hypodermically, and is therefore of the same nature as that in the other organs. The cells of the stomach first attacked are those of the glands, and the condition has been termed gastradenitis.

The **Liver** is early involved in the action of phosphorus, and Fischler and Burdach state that the fatal dose is much higher than usual in animals in which the poison is delayed in reaching that organ; they demonstrated this in dogs in which free communication had been established between the portal vein and the inferior cava, so that the liver circulation was reduced to the hepatic artery.

The fatty changes in the liver cause a considerable increase in the area of hepatic dulness, and at the same time induce some pain and tenderness over the organ.

In the earlier phases the secretion of bile pigment is increased, denoting an unwonted activity of the liver, but later as the cells become infiltrated with fat, they press on the bile capillaries and occlude them, so that the bile is absorbed into the bloodvessels and gives rise to jaundice. The secretion at this stage is clouded, viscous and not deeply pigmented, and appears to be derived mainly from the mucus cells of the smaller bile ducts and not from the liver cells proper. During recovery the cells lessen in size and cease to press on the ducts, and the bile loses its turbidity and viscosity, and is very dark in color, because the pigment which was deposited in the tissues during the second stage is reabsorbed and excreted; the jaundice color of course disappears from the skin as the bile pigment is reabsorbed. The bile very often contains albumin in considerable amount while the bile salts are reduced; in the later stages red blood cells may occur in it.

Other changes have been shown to occur in the liver in phosphorus poisoning; thus the proportion of water is increased while the glycogen and lecithin are reduced. When the distribution of the nitrogen is examined, it is found that a smaller proportion than usual is combined in the form of proteins, while a larger percentage is found in the form of simpler bodies such as ammonia and the amino-acids. When the liver of an unpoisoned animal is kept from putrefaction for some time, the tissue is broken down by the action of an autolytic ferment; in phosphorus poisoning it undergoes the same changes when preserved from putrefaction, but the autolysis progresses much more rapidly. Jacoby therefore infers that phosphorus augments the activity of the autolytic ferment of the liver and thus reduces the proteins, glycogen and lecithins, while increasing the simpler amino-acids. The acid formed in this process combines with ammonia. The ferments which decompose the amino-acids do not seem more active in phosphorus poisoning or in autolysis than normally, but only those which decompose the proteins to their simpler bodies. He regards the disappearance of the fibrinogen of the blood as a further effect of this liver autolysis, for he found that the injection of the autolytic ferment into normal animals prevented coagulation.

Much attention has been directed to the rapid disappearance of the glycogen of the liver in phosphorus poisoning; this is said to precede the other changes in the liver cells. When the glycogen of the liver is taken up under other conditions, it is either rapidly utilized as a source of energy under some special strain, or it gives rise to an excess of sugar in the blood. In phosphorus poisoning there is no special demand for carbohydrate which would be satisfied by the liberation and oxidation of sugar, and on the other hand there is no increase in the sugar of the blood, but rather a decrease. It has therefore been suggested that the glycogen is broken up with the formation of lactic acid owing to a specific action of phosphorus on the liver cells.

In the **Kidney**, the fatty degeneration of the epithelium may account for the albuminuria, which is not generally severe, and is not infrequently absent in cases of poisoning. Fatty casts and even globules of fat are often found in the urine in cases which run a chronic course. Blood and hæmoglobin may also appear in it from hæmorrhages into the kidney. The urine is normal in quantity in the early stages of the intoxication, but afterward becomes deficient, and towards death complete anuria may be observed.

The nitrogen of the urine varies considerably in different cases. Very often in the first few days after the ingestion of the poison, it is markedly diminished in amount from the prolonged nausea and vomiting, which prevents the absorption of food; the nitrogenous excretion thus corresponds to that during the first few days of starvation. After this, the nitrogen of the urine rises above what is usually excreted in starvation, even though the patient continues to fast. This increase is almost entirely confined to the ammonia of the urine, which is excreted as ammonium lactate, and the rise in the nitrogen elimination therefore seems due for the most part to the formation of lactic acid in excess in the tissues.

Some increase in the other nitrogenous constituents of the urine also occurs in phosphorus poisoning, and a number of amino-acids have been identified in it. The best known of these are tyrosin and leucin crystals, which are not always present in the urine, however, although they have been found in the blood in some quantity. The phosphates of the urine are often very considerably augmented, but not because of the excretion of phosphorus as phosphates, for the quantity absorbed is too small to cause any appreciable change. The increase in the phosphates is rather to be ascribed to an augmented waste of the tissues, and the sulphates are also excreted in larger quantity for the same reason.

When icterus is present, the urine may be dark in color from the bile pigment excreted, and bile acids are also often contained in it.

Metabolism.—The great similarity between the results of normal autolysis and of phosphorus poisoning has led to the view that the essential effect of phosphorus is an acceleration of the autolytic process, which occurs in normal

cells. This accelerated destructive metabolism is less completely carried out than normally, so that intermediate products, such as leucin, tyrosin and other amino-acids appear in large quantities in the organs and often in the excretions; lactic acid is similarly a product of autolysis, which fails to be oxidized to carbonic acid as in the normal body. This accelerated autolysis occurs not only in the liver but also in other organs, although in a less marked degree.

According to this view, the fatty infiltration is a secondary result of the accelerated autolysis; the cells are supposed to absorb fat from the blood more rapidly than normally and to store it in their interior in the form of globules, and as the fat of the blood is thus reduced, the normal fat deposits in the body are drawn upon to replace it and this results in the transference of fats from the subcutaneous tissues to such organs as the liver, kidney, and heart. But these have lost to a large extent their normal capacity of decomposing fats, which are therefore deposited in the cells.

Another view has recently been suggested, that the essential feature in phosphorus poisoning is the change in the carbohydrate metabolism; the liver forms lactic acid from its glycogen which it can no longer retain, and this lactic acid is neutralized by ammonia. The loss of carbohydrate causes a draft to be made on the proteins of the body, and an increase in the nitrogen excretion is the result. At the same time the want of carbohydrate in the liver leads to the mobilization of the fats, which stream into the liver to supply the deficiency; but they can no longer be utilized completely and are therefore deposited in the cells. The theory is attractive from its simplicity, but is not sufficiently established by experiment, and appears to neglect several accurate observations in which the protein waste was shown to be greater in phosphorus poisoning than in complete starvation.

In view of the curious effect of phosphorus on the tissue change of the vertebrates, its action upon simpler forms possesses some interest. It has been found, however, that yeast, infusoria and bacteria are very little affected by the presence of this poison, and living microbes are found in large numbers on solid pieces of phosphorus. The ferments are also unaffected for the most part, pepsin and pancreatin acting in the presence of phosphorus. The synthesis of hippuric acid in the kidney is lessened if to the blood used to perfuse the organ some phosphorus is added.

The **Temperature** is often low in the later stages of phosphorus poisoning, but slight fever is also observed in some cases.

The **Fate** of phosphorus in the body is still obscure. It is possible that some of it is oxidized to phosphoric acid, and some phosphorus is said to be excreted by the lungs, although the statement that the breath becomes phosphorescent seems to be extremely improbable. It is also excreted in the urine in some organic combinations, of which nothing is known, though they are said to be volatile. In pregnant animals poisoned with phosphorus the fœtus is found to undergo fatty degeneration, so that the poison would seem to pass through the placenta. Phosphorus injected hypodermically acts much more slowly than when swallowed.

Phosphuretted hydrogen (PH_3) induces the same symptoms as phosphorus, when it is given in repeated small quantities. Large doses are very rapidly fatal, and the symptoms differ entirely from those of phosphorus poisoning, consisting of marked dyspnœa, purgation, weakness, tremor, and finally violent convulsions and respiratory failure. The oxygen compounds do not seem to have any such effects, and for the most part are harmless except in very large doses.

Phosphorus (U. S. P., B. P.), a translucent, nearly colorless solid resembling wax in lustre and consistency. It emits white fumes in the air, which are luminous in the dark and take fire spontaneously. The fumes have the odor of garlic and in dilute solution phosphorus has a harsh, disagreeable taste. It is very little soluble in water, more so in alcohol, and dissolves to about 2 per cent. in fats and oils. 0.5 mg. ($\frac{1}{120}$ gr.) given in solution in oil or in pill form.

Phosphorus has been recommended for a variety of purposes in therapeutics,

but has never acquired an assured footing. Its action on bone has suggested its use in rickets, osteomalacia, ununited fractures and caries, but it has generally been given in cod-liver oil, which itself has a powerful action on rickets, and what little reputation phosphorus enjoys, it may owe to the menstruum in which it is prescribed.

Treatment of Phosphorus Poisoning.—Phosphorus is comparatively slowly absorbed from the alimentary canal, so that in the early stages an attempt ought to be made to remove it by emetics or the stomach tube, and by purges. Fats and oils must be avoided, as they tend to dissolve the poison and promote its absorption. Phosphorus has been found in the stools three days after its ingestion, and a sharp purge may therefore be of use up to this time.

Turpentine oil was formerly used with the object of oxidizing the phosphorus or of forming some compound with it in the stomach, but this treatment has proved quite valueless (Plavec). Sulphate of copper is recommended in phosphorus poisoning, a large dose being given first as an emetic, and afterward smaller doses to form an insoluble compound, copper phosphide. Permanganate of potassium solution, 1 per mille, has been recently advised to oxidize the phosphorus, while peroxide of hydrogen solution is of less value. In the secondary stage alkalies are recommended in order to neutralize the excess of lactic acid formed in the tissues.

Phosphorus necrosis has to be treated surgically on the same principles as other necroses of bone.

Hypophosphites and Glycerophosphates.

The hypophosphites have been used in therapeutics in the belief that they had some special influence on nutrition. They were formerly supposed to be oxidized in the tissues to the phosphates, but this has been shown to be incorrect, as practically the whole of the hypophosphite administered can be recovered unchanged from the urine. No entirely satisfactory work on the effects of these salts on the nutrition has been done, but there is no ground to suppose that they have any further action than the other indifferent salts, such as the chlorides. The hypophosphites of sodium, potassium, and calcium along with hypophosphorous acid are contained in the *Syrupus Hypophosphitum* (U. S. P.), which has been used in doses of 2 fl. drs. in various conditions of malnutrition and cachexia in the popular belief that it improves digestion and assimilation. This is quite without foundation.

The glycerophosphates have been employed in therapeutics in the same way as the hypophosphites, there being some vague idea that they improve nutrition and supply organic phosphorus compounds to the nervous system. As a matter of fact they are rapidly decomposed and the phosphate is excreted in the urine and stools as inorganic salts, while the glycerin undergoes combustion; the administration of glycerophosphates has thus no more effect than that of glycerin and inorganic phosphates. Their use in therapeutics is nil.

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LV. ARSENIC.

Some of the less active preparations of arsenic, such as the sulphides, Realgar (As_2S_2) and Orpiment (As_2S_3), have been known in therapeutics since the beginning of the Christian era, but this metal was brought into especial prominence in later times through the frequent use of the more dangerous oxides in criminal poisoning. Thus the notorious Aqua Tofana of the sixteenth and seventeenth centuries, owed its activity to the presence of arsenic, and various arsenical compounds have been used up to the last few years more largely than almost any other poison in suicide and homicide. This is to be explained by their having been widely employed in the arts, and thus being readily accessible to all, and by the general recognition of their poisonous nature. Of late years intentional arsenic poisoning has become somewhat less common, though on the other hand, accidental poisoning is still met with not infrequently, especially in the chronic forms. Many of these chronic cases are extremely difficult to diagnose, and probably often pass unrecognized by the attending physician. In view of this fact it seems desirable that more stringent measures should be taken to reduce the use of arsenic in the arts, and especially to prevent its being brought in contact with food. The danger of the use of the green arsenical dyes, such as Scheele's Green (arsenite of copper), and Schweinfurt's Green, or Paris Green (arsenite and acetate of copper), is now generally recognized, but arsenic is still used in the preparation of other colors, and these may give rise to poisoning from the imperfect removal of the metal. It has also been used in dilute solution to preserve food, and a solution is often sprayed upon grape vines and other plants to preserve them from the attacks of insects. Poisoning has occurred from these sources and is difficult to diagnose, as it is in some cases impossible to find the means by which the arsenic enters the system. A widespread epidemic of poisoning in England in 1900 drew attention to a source of arsenic which up to that time had not received the attention it merited. Several thousands of persons suffered from arsenic being contained in cheap beers made from glucose, in the manufacture of which sulphuric acid had been employed. The sulphuric acid was formed from iron pyrites containing arsenic, and the poison was carried from the sulphuric acid with the glucose into the beer. Sulphuric acid is used in the manufacture of so many drugs,

foods and other substances in constant use, that this intimation that it may convey arsenic into articles where its existence has not hitherto been suspected, is of the gravest importance.

Metallic arsenic is insoluble in water, and passes through the alimentary canal for the most part unchanged and without action, but it is possible that small quantities may be oxidized to arsenious acid in the stomach and intestine under some conditions. Some symptoms have been observed when it is rubbed on the skin in a state of fine division, and these are probably due to its absorption in the form of an oxide. The characteristic "arsenic" action is induced by the salts of trivalent arsenious acid (AsO_3H_3), and by its anhydride (As_2O_3), which is often known as arsenic, and which exists in the tissues as arsenites. Arsenic action is therefore due, not to the element, but to the ion of arsenious acid. The anhydride and salts of the pentavalent arsenic acid (H_3AsO_4) cause similar symptoms, but are less poisonous and act more slowly than those of arsenious acid, and may probably owe their effects to their being changed to arsenites in the tissues. The action being due to the ion and not to the element, it necessarily follows that compounds from which the ion is not liberated do not induce the arsenic action, or do so only when they are changed to bodies which can dissociate the arsenious acid ion. Thus organic arsenic combinations in which the metallic atom is directly attached to carbon are only feebly poisonous, but in course of time seem to be changed to arsenious acid in the tissues, and then cause typical poisoning.

Arsenious acid, which in the following pages will be taken as the representative of "arsenic" action, has a faint sweetish taste, and is therefore not so likely to be detected by the victim as many of the other poisons.

Symptoms.—In large quantities arsenic very often causes no symptoms for half an hour or more, but then the patient complains of a feeling of constriction in the throat, of difficulty in swallowing, and of discomfort in the stomach region. This soon increases to violent pain, and is accompanied by vomiting, and later by watery diarrhœa. The stools are at first of ordinary diarrhœic appearance, but later resemble the "rice-water" stools of cholera, in that they consist almost entirely of minute shreds of disintegrated mucous membrane suspended in a serous fluid; sometimes, however, they are clear and gelatinous in appearance. In some cases, blood appears in the vomited matter and also in the stools, but this is not by any means an invariable feature. The urine is diminished, or entirely suppressed, from the great amount of fluid eliminated by the stomach and bowel. These symptoms from the alimentary tract are accompanied by giddiness, cramps in the muscles, headache, and soon by collapse, with cold damp skin, pallor, feeble pulse and weak, sighing respiration; this later passes into coma, and death follows with or without convulsions. In cases in which the dose is smaller than the fatal one, or in which much of the poison is eliminated by vomiting, the patient may recover without further symptoms than those already described. Frequently, how-

ever, he recovers from the acute symptoms only to develop those of chronic arsenical poisoning. In some instances it is said that no symptoms are present except those of collapse and coma. In acute poisoning death may occur within twenty-four hours, but more frequently the patient lives for two to four days or longer, and then succumbs to exhaustion. The fatal dose is uncertain, because arsenic is very insoluble, especially when in coarse particles, and thus large amounts (2 G.) have been swallowed in solid form with impunity and have been recovered from the stools unchanged; even when more soluble preparations are taken, much may be rejected by vomiting. Fatal poisoning has occurred from about 0.1 G. of arsenic in solution.

Chronic Arsenic Poisoning may arise from a single large dose, the effects persisting for weeks or months after the ingestion and new symptoms arising as the earlier ones disappear; more frequently, however, it is induced by the prolonged absorption of small quantities. The milder symptoms may arise from its therapeutic use, but typical cases are generally due to the presence of arsenic in the form of dyes in wall paper or clothes, or in stuffed animals in the rooms inhabited by the victims, or to the constant handling of arsenical pigments and other compounds in mines and manufactories. Widespread poisoning has been observed from the use of wines containing arsenic at Hyeres in France, from milk diluted with arsenical water in London, and from beer in the Manchester district. In these last cases the arsenic was in solution, but it often seems to be inhaled in the form of fine dust, which falls from the walls or other objects.

The symptoms of chronic arsenic poisoning, which are often very obscure, may be divided into three phases. In the first of these, the patient complains of weakness and languor, loss of appetite, some nausea and occasionally vomiting, with a sense of heaviness and discomfort in the stomach. Diarrhœa may be present, but is often absent, and in fact some constipation may occur.

In the *second* phase the conjunctiva is often red and inflamed, and symptoms of coryza appear, with sneezing, hoarseness and coughing, from a catarrhal condition of the mucous membranes of the nose and larynx. Some swelling of the liver and jaundice may occur, but these are not generally well marked. Skin eruptions of various forms—papular, vesicular, or erythematous—are generally noted; very often the epidermis falls off in fine brownish scales, or, in the hands and feet, in large flakes (keratosis); a curious pigmentation is very common, the skin assuming a dark metallic color resembling in extreme forms that produced by rubbing a lead pencil upon it (arsenic melanosis). This pigmentation is much more marked in persons of dark complexion than in fair people, in whom it may be indistinguishable from ordinary freckles; it generally disappears when the patient is removed from the poisonous atmosphere, but has been permanent in some cases. In prolonged poisoning the eruptions may simulate almost any form of skin disease, and the hair and nails fall off. Herpes is not infrequently observed and points to nervous disturbances such as are prominent features in the next phase.

These phases are not always distinct in cases of poisoning, and very often some of the symptoms of the second phase may appear before any marked disorder of the digestive tract. In the prolonged therapeutic use of arsenic, the first indications of commencing poisoning are redness, suffusion and swelling of the conjunctiva and eyelids, and dryness of the nose and throat, as in coryza. On the other hand, in workmen exposed to arsenical dust, the first symptoms may arise from the skin or from bronchial irritation.

The *third phase* is marked by disturbance of sensation and motion in localized areas, generally in the hands and feet (peripheral neuritis). It is often ushered in by intense persistent headache or by acute pain located around the knee, ankle or foot, less frequently in the wrist and hand. The patient complains of formication in the extremities, and of the discomfort caused by the pressure of the bed-clothes on the feet and legs. The palms of the hands and the soles of the feet are often red, swollen and extremely sensitive to touch (erythromelalgia), and pressure on the muscles induces the most intense pain. Later, sensory paralysis may set in, especially in the extremities, and the less acute sense of touch in the feet and hands induces symptoms resembling those of locomotor ataxia. The sensitiveness to heat and cold may be exaggerated or dulled, or sometimes heat is not appreciated, while cold causes intense pain. The sense of pain varies in different cases, in some being abnormally acute, in others deadened. These sensory disturbances are followed in severe poisoning by motor paralysis, which generally appears in the extensor muscles of the toes, later in the peronei muscles. More rarely the flexor muscles of the leg and foot are involved, and in some cases the affection commences in the extensors of the hand and fingers. As a general rule the paralysis is confined to the extremities, but in some cases it has been found to invade the trunk. It is generally, but not invariably, symmetrical, and the muscles affected atrophy rapidly, and present the reaction of degeneration. There is sometimes some difficulty experienced in diagnosing arsenic from lead paralysis, but in the former there is often a history of acute poisoning, while the latter is almost invariably due to prolonged absorption. Disturbances of sensation are much more common in arsenic than in lead palsy, and in the latter the forearm muscles are generally affected first, in the former those of the leg. In arsenic poisoning atrophy is said to occur more rapidly, and there is no line on the gums. Another condition which presents still greater difficulties in diagnosis is alcoholic neuritis. But in the latter skin eruptions are rare, coryza is not present, and there are generally more marked brain symptoms than in arsenical cases. In doubtful cases the urine and the hair of the patient should be tested for arsenic.

Arsenic paralysis may appear as early as three days after an acute intoxication, but is commonly observed later, and may occur only after three or four weeks.

In very prolonged arsenic poisoning the patient may sink into an apathetic, semi-idiotic condition, or may become epileptic. In most

cases the symptoms slowly disappear when the poison is removed, but even slight paralysis may last for many years before it is entirely cured, and after complete degeneration of the muscles little improvement is to be expected. The contractures which follow are generally due to the unopposed action of the sound muscles, but sometimes arise from the shortening of the paralyzed ones.

Therapeutic Doses of arsenic often improve the appetite and digestion, and its prolonged administration has been credited with increasing the assimilation of the food, retarding the tissue waste, and thus leading to acceleration of growth and increase in weight. An improved nutrition of the skin and some alteration in the blood cells is generally believed to arise from the use of arsenic in quantities too small to induce chronic poisoning.

Action.—Arsenites and arsenious acid do not coagulate proteins or change them in any way, except when applied in such enormous quantities as never reach the stomach, so that the action of arsenic on the **Alimentary Canal** cannot be explained as due to any ordinary form of corrosion, although the symptoms and the post-mortem appearances resemble in many points those of the corrosive poisons. Thus the mucous membrane of the stomach is generally found red and swollen, and often contains hæmorrhages. The epithelial coat can be rubbed off very easily, and is found to be in a state of fatty infiltration, and sometimes resembles a false membrane; or the only lesion may be cloudy swelling and fatty infiltration of the gland-cells.

The intestine presents very similar appearances, the mucous membrane being swollen and congested, more especially around Peyer's patches. It contains a quantity of thin fluid with flakes of membrane, resembling exactly the rice-water stools of cholera, from which it is difficult to distinguish it.

The same symptoms arise when arsenic is absorbed from the subcutaneous tissue, or from the broken skin, though only traces of arsenic are found in the contents of the stomach and intestine when it is ingested in this way.

The failure to explain the gastro-intestinal action of arsenic by ordinary corrosion has led to the suggestion that it is due to the extreme dilatation of the intestinal vessels, which gives rise to the congestion and swelling, and this in turn to the destruction of the lining membrane, perhaps by the exudation of fluid beneath the epithelium. This transudation of fluid is certainly in accord with the watery character of the stools in arsenic poisoning, but the explanation does not seem entirely satisfactory, for it fails to account for the fatty infiltration and the cloudy swelling of the epithelium, which are in some cases the only lesions found here. The fatty infiltration is not confined to the stomach and bowel, but involves a number of other organs, although it is not as a general rule so widely distributed as in phosphorus poisoning. Arsenic then must be considered to have a specific action in causing fatty infiltration of the epithelium of the stomach and intestine. This in

itself is sufficient to explain many of the symptoms from these organs, although it may well be that the vascular action is the cause of the excess of fluid in the intestine, and in fact, the fatty infiltration alone is insufficient to explain this feature, which is absent in phosphorus poisoning.

In therapeutic doses arsenic is said to increase the appetite and promote digestion, an effect which may perhaps be due to the specific action on the epithelium, this in its milder forms proving of advantage to the organ, though in excess it leads to its degeneration; it has been observed in dogs with gastric fistulæ that the gastric secretion is augmented by small quantities of arsenic.

Circulation.—In the frog the heart is slow, weak, and irregular, and ceases in diastole after comparatively small doses; the action seems to be a direct paralysis of the muscle. In the mammal the heart is little affected by arsenic, but a very marked fall of the blood pressure follows the injection of large doses intravenously. This is due to dilation of the capillaries from a direct action on their walls; adrenaline and nicotine continue to raise the blood-pressure after arsenic, because the arterial wall can still respond to strong nervous impulses; the vessels of the splanchnic area seem more susceptible to this arsenic action than those of the rest of the body, and their dilation leads to very marked congestion of the stomach and bowel, and reduces the blood-pressure to zero. The dilated capillaries permit the passage of fluid into the tissues more readily than normally, and this explains the appearance of œdema in cases of poisoning and also the large amount of fluid in the stools and vomited matter. Arsenic is therefore often termed a capillary poison.

Respiration.—In cases of poisoning in man the respiration does not seem to be much affected until late, but it ceases before the heart, probably from the exhaustion and low blood-pressure, and not from any specific action on the centre.

The action of arsenic on the **Central Nervous System** has been repeatedly examined. A descending paralysis is elicited in the frog, the animal first losing its spontaneous movements, and then its reflexes, and the terminations of the motor nerves being involved only very late in the intoxication. In mammals there are generally no certain indications of direct action on the nervous system in acute poisoning, for the weakness and prostration, and the final loss of consciousness and coma may be attributed to the exhaustion from the gastro-intestinal effects rather than to the centres being immediately affected.

The pathology of the nervous disturbances observed in chronic poisoning, and often after a single large but not immediately fatal dose, bears no relation to the effects observed in animals in acute poisoning. The symptoms in chronic poisoning all point to peripheral neuritis as the cause, and the characteristic lesions in the nerve trunks have been shown to occur both in man and animals exposed to the prolonged action of arsenic. In severe cases the spinal cord may also

be involved secondarily. The peripheral muscles and nerves are little affected in acute poisoning.

The unbroken **Skin** is not affected by arsenic, unless when it is applied repeatedly or allowed to remain in contact with it for some time, when it may give rise to redness, pustules or vesicles and later to violent erysipelatoid inflammation. It has not, however, any such corrosive action on the skin as is possessed by strong acids, and the subcutaneous injection of arsenic is not painful at first. It is more active when applied to denuded surfaces and to the mucous membranes, destroying them to some depth and causing acute pain, but even here it acts more slowly than ordinary caustics. It seems to act only upon living cells, and unlike acids and alkalies, forms no combinations with the dead tissues. The local effects of arsenic on the skin are seen only in workmen handling arsenic, as in color factories, in which affections of the skin of the face, hands and scrotum are by no means rare.

In chronic arsenic poisoning skin eruptions are common, and are to be ascribed to the direct action of the drug on the skin. This appears to accelerate the growth and proliferation of the epithelium, which is found to be increased in thickness, but which in very severe cases shows signs of atrophy and degeneration. Arsenic has been found in appreciable amount in the hair and epidermal scales, and in the fluid of a blister in patients treated with it, and changes in the condition of the skin in animals have also been observed.

The melanosis of arsenic poisoning seems to be due to the deposition not of an arsenical compound, but of some organic product in the deeper layers of the corium. The symptoms of irritation of the mucous membranes of the eye, nose and larynx are analogous to the skin eruptions.

The action of arsenic on **The Blood** is still obscure, although it is frequently prescribed in various forms of anæmia. In chlorosis and in normal persons, it is said to diminish the number of the red corpuscles, but not to alter the total hæmoglobin of the blood. Stockman and Greig found the blood cells and hæmoglobin unaltered by arsenic in normal animals, but describe the bone-marrow as evidently in a state of unusual activity, indicated by its increased vascularity, greater number of red-blood corpuscles and lessened fat cells. In a case of pernicious anæmia recently examined by Engel, it was found that arsenic increased the number of young newly formed red cells while the number of more mature corpuscles was diminished. Bettman states that in subacute poisoning in rabbits, the red cells and hæmoglobin are diminished, and nucleated red cells appear in the blood in some number; and from this it has been suggested that arsenic may accelerate the destruction of the blood cells and thus induce a more rapid formation indirectly as a sort of compensation; but there is no evidence that therapeutic doses increase the destruction of the blood cells and this view may be dismissed as fanciful. Gunn has shown that in shed blood small quantities of arsenite protect the red cells from various hæmolytic agents and suggests that this may occur in the therapeutic use of

arsenic. After hæmorrhage the blood is said to regenerate more quickly if arsenic is given, and the number of red cells rises faster than the hæmoglobin.

The **Metabolism** is affected by a poisonous dose of arsenic in the same way as by phosphorus, but the alteration is not generally so marked and is liable to be overlooked, owing to the more intense action on the alimentary canal. The nitrogen of the urine is considerably greater than that of inanition, but it is not quite clear whether this is due to an increase in the urea or to other nitrogenous substances. The ammonia is probably augmented, for a considerable amount of lactic acid has been obtained from the urine. The glycogen of the liver disappears entirely, and the liver seems incapable of forming it from the sugar of the food; it is said that under arsenic treatment quantities of sugar can be assimilated, which would normally be sufficient to cause glycosuria. Lesion of the medulla oblongata (diabetes puncture) does not cause glycosuria after arsenic, but curara and other drugs are still capable of eliciting this symptom. The fatty degeneration of the epithelium of the stomach and intestine has been mentioned already, but this alteration is not confined to these tissues, being found in the liver and kidney, in the muscle cells of the heart, bloodvessels and striated muscles, and in the lining epithelium of the alveoli of the lungs. Small necrotic foci have been observed by Wolkow in the liver, along with signs of active division of the parenchymatous cells, as in phosphorus poisoning. The catalase of the blood and tissues is said to be increased by therapeutic doses in poorly nourished animals, while this change does not occur in strong and healthy individuals. When the capillary damage is extensive in arsenical poisoning, the available alkali of the blood is reduced, as is the case under other capillary poisons.

The changes in the metabolism under arsenic resemble those under phosphorus, so that they have generally been regarded as arising from a similar action. The action on the autolytic ferment was said to be diametrically opposite, but it appears that small quantities of arsenic, corresponding to those causing chronic poisoning, accelerate autolysis in the same way as phosphorus; very large amounts may arrest the autolysis by destroying the ferment. But arsenic in small doses has much less influence on the tissue change than phosphorus.

The fatty infiltration may have the same results as in phosphorus poisoning. The liver is somewhat enlarged and the pressure on the bile ducts prevents the escape of bile into the intestine, and thus induces jaundice and the appearance of bile pigments and bile acids in the urine. Jaundice is seldom, however, a very marked feature in arsenic poisoning, and is often entirely absent. The bile is said to contain albumin, red-blood cells, and casts, as in phosphorus poisoning, but does not present other changes except immediately before death.

The prolonged administration of arsenic in quantities insufficient to produce chronic poisoning is reputed to have some effect on the **Growth and Nutrition**, but while improved nutrition is attested by a number of the older observers, other equally careful investigators have

not been able to confirm their results. Thus Stockman and Greig observed no change in the growth of animals under prolonged treatment with arsenic, and found that the only tissues affected were the growing bones, which appeared denser than usual. Sollmann feeding rats with very small quantities, far below the corresponding therapeutic dose in man, found that these tended to lessen appetite and retard the growth of the animals. The results of these careful researches are thus opposed to the popular view that arsenic is a "tonic" and exercises an invigorating action on the nutrition in man.

Attempts made to substantiate this view by measurement of the nitrogen metabolism have led to divergent results in the hands of different workers, and even in the more favorable cases, the change is so small that doubt may be entertained whether it may not have arisen from unavoidable error in these very long and tedious investigations. Several workers on the subject state that the bone formation may be altered, while denying any other influences on the metabolism.

Another widely held view is that the habitual use of small quantities of arsenic leads to **Tolerance**, and that the dose may be gradually increased until it far exceeds that which would be poisonous in ordinary persons. This is given as the explanation of arsenic-eating which is known to exist in different parts of the world, but which is most widespread and best known in Styria and the Tyrol. The peasants there indulge in the poison habitually, and believe that it enables them to work better, and in particular to climb the mountains with less effort and less respiratory distress. Knapp administered 0.4 G. (7 grs.) of arsenious acid to one of the peasants at Graz without inducing any effects whatsoever. Arsenic-eating is said to be indulged in to a considerable extent by young women in some countries with the object of improving the complexion and figure, and cases of arsenic habit have been described in different parts of America and elsewhere. As far as can be observed, the habit is not deleterious, for the Styrian peasants live to old age, and no symptoms attributable to the poison have been noted. As a general rule large doses are taken once or twice a week, and no fluid is swallowed for some time afterwards.

It is also stated that large doses can be taken with impunity by animals previously treated with increasing quantities of dry arsenic by the mouth; on the other hand this has not been observed under arsenic given in solution hypodermically, and the statement is made that animals that tolerate large quantities by the mouth are killed by small quantities injected in this way. This has led to the view that in tolerance the intestinal cells fail to absorb the arsenic, and the poison thus does not reach the body cells, which remain susceptible to it. Thus Joachimoglu holds that tolerance is limited to the intestinal cells, which no longer undergo inflammation and necrosis under arsenic. But considerable quantities of arsenic have been found in the urine of arsenic-eaters, showing that absorption occurs. Unfortunately these experiments and observations have not taken account of the great variation in the fatal dose of dry arsenic taken by the mouth; when coarse powder is taken,

many times as much arsenic may be taken as when a fine powder is swallowed, and still less is dangerous when a solution is employed. And no tolerance has been definitely shown to be developed when the drug is given in solution; until this has been done, the development of tolerance to arsenic has not been demonstrated; the whole question requires further examination.

As a contrast to the Styrian peasants, the miners of Reichenstein may be mentioned, who are constantly exposed to arsenic owing to its being contained in large quantities in the ore. These people are described by Geyer as shortlived, very subject in childhood to severe rickets and in adult life to dropsies and respiratory diseases; they offer little resistance to microbial infection and frequently present the skin and nervous symptoms of arsenic poisoning. The difference in the reactions of these people may arise from the Styrians swallowing the dry crystals, which fail to be dissolved and absorbed, while the oreworkers may be exposed to a finer powder, which may perhaps reach the blood through the lungs. Differences in the general nutrition may also play a part, for Delepine and others have found that animals supplied with abundant food and in good hygienic conditions survive under chronic arsenic poisoning much longer than less well nourished ones. This difference in the nutrition may also explain the fact that in epidemic poisoning, as in the Manchester cases, comparatively few of the persons exposed to the poison exhibited any symptoms from it.

Arsenic is **Excreted** very slowly, some appearing in the urine and fæces within twenty-four hours, but only about one-fifth of that absorbed being eliminated in this way. The rest is stored in the tissues for a long time and slowly got rid of in the hair and epidermis, in which arsenic may be found for many months after it has disappeared from the urine and fæces. Traces may be found in other secretions, and fatal intoxication has been observed in a child from the milk of its mother, who was suffering from acute poisoning. In the urine arsenic appears as arsenite and arsenate. It is probable that the effects, especially the paralysis, last long after the drug has been excreted, lesions having been induced which only recover slowly.

Arsenic disappears rapidly from the blood when injected, being taken up by the tissues in which it forms firm combinations with the nucleins; it is found chiefly in the liver, and is also deposited in the kidney, in the walls of the stomach and intestine, and in the spleen and lungs. Much smaller quantities are found in the muscles and in the nervous tissues, in which it is said to occur in larger proportion in the white than in the gray matter. It has been detected in the cancellous bones of the skull and vertebræ, after it had disappeared from all the other organs.

Arsenic is poisonous to many of the lower forms of life, as well as to the vertebrates; thus it has been found that its presence in comparatively dilute solution (one part of arsenious acid in 30,000 parts of water) hinders the development of, and eventually kills, algæ and the seeds of the higher plants. On the other hand, moulds grow abundantly in a solution of potassium arsenite (1 per

cent.) containing some organic matter, and the alcoholic fermentation proceeds in the presence of arsenic, although it is somewhat retarded at first; very dilute solutions of arsenic even accelerate the fermentation, as is true of most other antiseptics. Arsenious acid is only about one-tenth as strong an antiseptic as perchloride of mercury, and the spores of anthrax are destroyed only after ten days in a one per mille solution. It has therefore a greater antiseptic power than many of the other acids, but compared with its action on the higher forms of life, it is but slightly poisonous to the fungi. It seems to have no effect on the activity of the ferments, such as pepsin, myrosin, and emulsin. Some pathogenic protozoa are extraordinarily susceptible to the action of arsenic; thus a concentration of arsenic in the blood of 1 in 200,000 is sufficient to destroy many of the trypanosomes, while other protozoa living in water may survive in a 1 in 5,000 solution. All the parasitic protozoa are not so readily destroyed, however, for that of malaria is found to be much more resistant. When an animal infected with trypanosomes is treated with arsenic, the parasites often disappear from the blood for some days or weeks and then reappear, but can again be expelled by arsenic, though for a shorter time; this phenomenon of developed tolerance is better seen when these organisms are treated with organic arsenic compounds and will be discussed later (p. 606). Apparently infusoria also acquire a certain tolerance of arsenic and other metallic poisons in water, but the very high resistance seen in the trypanosomes in the blood has not been observed in these non-parasitic protozoa.

The arsenates are much less harmful to lowly organized forms, for seeds and algæ as well as moulds grow in a neutral solution abundantly, and even the infusoria do not seem injured by it to any marked degree. Apparently these plants and animals are incapable of reducing the arsenates to arsenites, which are much more toxic.

The bodies of persons poisoned with arsenic are said to remain undecomposed for a remarkably long time, and to tend to become mummified. The statement is still disputed, but is vouched for by a number of authorities. It is certainly not invariably the case, and little weight is to be laid upon mummification in determining whether arsenic poisoning was the cause of death in exhumed persons.

No account of the pharmacology of arsenic would be complete without mention of the theory advanced by Binz and Schulz to explain its action. They suppose that arsenious acid is oxidized to arsenic acid by the living tissues, and the arsenic acid again reduced to arsenious. In this way oxygen is alternately withdrawn from and supplied to the protoplasm, and this alternate reduction and oxidation they suppose to be the essential feature of the action of arsenic. The grounds on which this explanation is based must be sought in the numerous papers on the subject by these authors, and it may suffice here to state that while arsenic acid appears to be reduced and arsenious acid oxidized in the tissues, these processes are probably only gradual. Otherwise it would be difficult to explain how arsenious acid is so much more poisonous than arsenic acid, for if the latter were readily reduced to arsenious acid it would be equally toxic.

Arsenic and phosphorus are included in one group in chemistry, and their effects on living organisms present sufficient resemblance to justify their association in the pharmacological system. The mucous membranes and the skin are more affected by arsenic, however, and the circulation is more rapidly depressed, while the fatty infiltration is much more prominent in phosphorus poisoning. The differences between their effects are more in degree than in kind, and there seems no question that their ultimate action on protoplasm is of the same nature. It is to be noted, however, that there is no reason to suppose that phosphorus owes its action to any of its numerous compounds with

oxygen, while it is probable that the oxides of arsenic alone are capable of modifying vital functions.

The **Sulphur Compounds** of arsenic are entirely insoluble and are therefore not absorbed as such, but it seems likely that small quantities of arsenious acid are formed from them in the intestine by microbes. Commercial orpiment often contains large amounts of arsenious acid.

Arseniuretted Hydrogen (AsH_3) is an exceedingly poisonous gas, which has caused a number of fatal accidents from being inhaled accidentally in chemical laboratories. Its action is quite different from that of the oxides of arsenic and there is no reason to suppose that arsenites give rise to appreciable amounts of the gas in the body, or that the effects of the latter are due to the formation of arsenites. Its action arises from its great affinity for hæmoglobin, which takes it up in large quantity and combines with it or with some product derived from it. This leads to hæmolysis, and the hæmoglobin liberated induces severe symptoms in the course of its excretion. In the test-tube arseniuretted hydrogen forms a combination with hæmoglobin which gives a characteristic spectrum, but this has not been shown to occur in living animals. Most of the symptoms appear to arise from the hæmolysis, but there may be in addition some direct action on the central nervous system.

Arseniuretted hydrogen induces intense headache, nausea and vomiting, prostration and fainting fits, cyanosis and collapse. Hæmoglobin, methæmoglobin, hæmatin and occasionally blood are passed in the urine, and more rarely the stools contain blood. Sometimes the urine is entirely suppressed from the tubules being plugged with blood cells and debris, and intense icterus appears from the formation of excess of bile-pigment from the hæmoglobin of the disintegrated corpuscles. Œdema of the lungs or sudden failure of the heart is the cause of death. Some of the gas is excreted by the lungs, and may be recognized by its garlic odor, and some arsenic appears in the urine, but it is not known in what form. It is estimated that one part in 100,000 parts of air is injurious to man if breathed for a few hours.

Preparations.

Arseni Trioxidum (U. S. P.), Acidum Arseniosum (B. P.) (As_2O_3), arsenous or arsenious, acid anhydride, white arsenic, ratsbane, forms a white powder, or opaque, porcelain-like masses, or a transparent, amorphous surface like glass. It dissolves slowly in cold water, the glassy variety requiring about thirty, the porcelain about eighty parts of water. It is almost tasteless and has no odor. 0.002 G.. ($\frac{1}{30}$ gr.); B. P., $\frac{1}{64}$–$\frac{1}{16}$ gr., in pill or solution, after meals.

Liquor Acidi Arsenosi (U. S. P.), Liquor Arsenici Hydrochloricus (B. P.), a 1 per cent. solution of arsenous anhydride acidulated with hydrochloric acid. 0.2 mil (3 mins.); B. P., 2–8 mins., after meals.

Liquor Potassii Arsenitis (U. S. P.), Liquor Arsenicalis (B. P.), Fowler's solution, contains 1 per cent. of arsenous anhydride rendered alkaline with bicarbonate of potash, to which compound tincture of lavender is added to give color and flavor. 0.2 mil (3 mins.); B. P., 2–8 mins., after meals.

Liquor Arseni (*Arsenii*, B. P.) *et Hydrargyri Iodidi* (U. S. P., B. P.), Donovan's solution, contains 1 per cent. of arsenic iodide and 1 per cent. of red mercuric iodide. This solution is clear and yellowish, without odor, but with a harsh metallic taste. 0.1 mil ($1\frac{1}{2}$ mins.); B. P., 5–20 mins., after meals.

Some mineral waters contain arsenic, that of Levico as much as 8 mgs. per litre.

Therapeutic Uses.—The action of arsenic as ascertained from experiments on the lower animals and from cases of poisoning in man throws little light on its use in therapeutics, and so little is known of the

pathology of most of the conditions in which it is found of benefit, that no attempt can be made to bring the two series of observations into relation. The treatment of trypanosoma infections, such as sleeping sickness, with arsenic and its compounds has given rise to the idea that many of the conditions in which arsenic is useful may arise from protozoal infection. But there is no question that arsenic acts in other ways than by destroying parasites, and such speculation is futile until the cause of these diseases has been determined.

Arsenious acid has been used externally as a caustic, formerly in various forms of malignant disease, more recently in lupus, in which it is said to destroy the diseased surface while leaving the healthy skin unaffected. It has been superseded, however, by the introduction of surgical measures and treatment with light rays. Arsenous anhydride is still used in dentistry to destroy the pulp in decayed teeth; this destructive, caustic action proceeds more slowly than under more violent corrosives, so that there is little or no pain from it.

Internally arsenic is used in malarial disease, especially in inveterate cases in which there is much cachexia. In acute cases it is also of benefit, but is much less certain in its effects than quinine; it may act here by improving the general nutrition and lessening the cachexia and wasting, but in addition arsenic acts on the malarial parasite, though less powerfully than quinine. Many authorities, in fact, deprecate the use of arsenic in acute malaria, and would limit its use to the cachexia of old disease, while others advise its use with iron in ordinary cases, after the acute stage has been successfully treated with quinine. In obstinate cases it is probable that the quinine action may be reinforced by arsenic, and that parasites which have a low susceptibility to quinine, may succumb to the arsenic. Thus while malaria generally does not require the use of arsenic, if the disease does not yield to quinine carefully administered, the patient may be treated with arsenic and quinine together.

Arsenic has also been used with benefit in neuralgia and in chronic rheumatism, but in many cases no definite improvement follows, and the conditions under which it is of value cannot be more accurately defined at the present time. Old cases of chorea often improve under arsenic, which may imply some action on the central nervous system, although as has been stated, little alteration in the nervous functions is observed in animals except under very large doses. Asthma has also been treated with arsenic with benefit in some cases.

Small doses of arsenic are often of service in increasing the appetite and improving the general condition in diseases accompanied by cachexia, want of appetite, general weakness and apathy.

In pernicious anæmia, arsenic is said to be beneficial, but the improvement is only temporary. Many forms of skin disease are treated with arsenic, some of them with the happiest results. Thus in psoriasis, chronic eczema, and lichen ruber, marked improvement or complete recovery often dates from the beginning of the arsenic treatment. It is generally advised only in the chronic forms, and is said to be

positively deleterious during the earlier stages of rapid cell proliferation.

In lymphoma arsenic has been given internally and also by direct injection into the tumors, and often, though not by any means invariably, proves of value. Various other forms of leucæmia have been treated with less success.

Arsenic has been used in syphilis in combination with mercury for over a century, and attention has again been drawn to this action through the efficacy of its new organic compounds. For this purpose Donovan's solution of the iodides of arsenic and mercury has generally been used. The quantity of iodide present in this solution is insufficient to have any specific iodide action and the improvement under it must thus be credited to the arsenic and mercury.

Arsenic has been used in some forms of trypanosoma infection in animals, and has been found to improve similar conditions in man. The ordinary preparations are less often used than atoxyl and related substances, but the trypanosomes show less tendency to become resistant to the inorganic forms and it is now recommended that these diseases should be treated by both inorganic and organic compounds. Arsenic is undoubtedly of great benefit in these diseases, relieving the symptoms and prolonging life even in those cases in which it does not actually cure the infection.

Arsenic is in the great majority of cases prescribed in the form of Fowler's solution. It is generally advisable to commence with small doses, and to increase them slowly as long as no symptoms follow, but some authorities advise large doses from the outset. Arsenic is always prescribed to be taken after meals, in order to avoid any possible action on the digestion. It is contra-indicated in cases of irritation of the stomach and bowel, and is generally avoided during acute fever, except in malaria.

If symptoms of chronic poisoning begin to assert themselves, the drug must be discontinued at once. The first symptoms are generally disordered digestion, loss of appetite and discomfort in the stomach region, a feeling of constriction in the throat, and redness and swelling of the conjunctiva and eyelids.

In Acute Arsenic Poisoning the stomach ought to be emptied at once by means of the stomach tube or by an emetic (apomorphine). The stomach washing is to be continued for some time, as arsenic is very insoluble. Iron or magnesium preparations have been advised in order to form a loose chemical combination with the arsenic; freshly precipitated iron hydrate formed by adding magnesia to a solution of iron sulphate forms the well-known arsenic antidote, or magnesia alone is sometimes given shaken up with water. Experiments on animals show that these antidotes are useless and that reliance is to be placed on repeated and copious lavage only.

The collapse is treated by the ordinary measures, warmth and stimulants, such as caffeine and digitalis. In chronic poisoning, the paralysis is treated by stimulating the muscles with the galvanic current, the other symptoms by suitable general treatment.

insoluble in the pill form.

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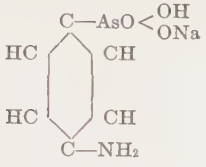
LVI. ORGANIC ARSENIC COMBINATIONS.

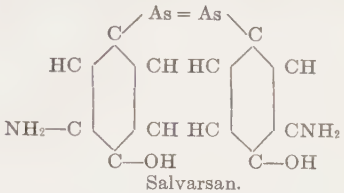
Inorganic arsenic has long had some reputation in the treatment of malaria and syphilis; in the latter it has been used along with mercury in the well-known Donovan's solution. These diseases have been shown to arise from animal parasites living in the blood and tissues, and when the sleeping sickness of Africa was found to arise from trypanosomes, another protozoan parasite, inorganic arsenic was used to treat it. The results were disappointing, as the quantity of arsenic that could be given was limited owing to its poisonous action on the patient. For inorganic arsenic proved to have little specific affinity for the parasite; in Ehrlich's phraseology, it was not parasitotropic, while it was very poisonous to the tissues of the host, or strongly organotropic. In the test-tube the inorganic arsenic preparations are very poisonous to the trypanosomes, and they would doubtless be equally destructive

in the tissues if they could be applied there without the destruction of the host.

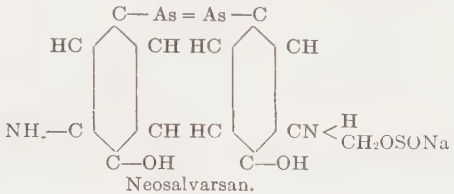
Some organic preparations of arsenic proved available for treatment, the first being *Atoxyl*, or sodium arsanilate. Later a modification of atoxyl



Atoxyl.



Salvarsan.



Neosalvarsan.

known as *Arsacetin* (acetylatoxyl, $CH_3CONH—C_6H_4—AsO<\frac{OH}{ONa}$ was found more active in combating trypanosoma infections. These combinations proved useful in syphilis also, but while destroying the parasites in these diseases, they were not devoid of deleterious action in man and have already almost disappeared from therapeutics. Ehrlich soon pointed out that atoxyl has practically no action on trypanosomes in test-tube experiments and only gains its parasiticide action in the tissues. He explains this by the view that the pentavalent arsenic compounds, such as atoxyl and arsenic acid, are really inactive in themselves and only acquire activity when they are changed to the trivalent arsenic, such as exists in arsenites.

This led him to seek for organic compounds in which the arsenic is trivalent, and two of these were introduced by him, *Arsenophenylglycin* and *Salvarsan* $(AsC_6H_3OHNH_2)_2 2HCl$, of which the latter has been very widely used in the treatment of syphilis. More recently a modification of salvarsan, *Neosalvarsan*, has been used instead of the parent substance. All of these organic compounds are much less poisonous to man and the higher animals than inorganic arsenic, while they maintain the poisonous action toward the protozoa that infest the blood and tissues. In other words they are less organotropic and more parasitotropic. Ehrlich supposes that certain parts of the molecule in these compounds attach themselves to the parasites, and that these haptophoric groups then allow the poisonous part, or toxophoric groups, to act on the protozoa. The tissues of the mammals do not afford points of attachment for the haptophoric groups and therefore are not attacked by the toxophoric radical. A simpler view is that the organic compounds permeate readily into the parasite and there are decomposed, possibly to inorganic arsenic, and thus prove poisonous

to the protozoa; the mammalian cell is less readily permeated by the organic forms and thus escapes being destroyed by them.

The treatment of trypanosoma infections with arsenic preparations has proved less successful than the first applications seemed to promise, owing to the parasites rapidly becoming tolerant to the drug. If an animal infected with trypanosomes receives an injection of atoxyl, the parasites disappear from the blood and none may be found in it for many days or weeks; then a few reappear and rapidly multiply but are again destroyed by a second dose; the interval before they are again seen in the blood is shorter, and becomes shorter with each succeeding injection until atoxyl no longer frees the blood from trypanosomes even in the maximal dose which can be given without injury to the host. If a second animal is now infected with the blood of the first containing these resistant trypanosomes, it is not improved by atoxyl, the descendants of the resistant type maintaining their tolerance of atoxyl through an indefinite series of generations. This form of resistance appears to arise from a process of selection by the survival of the most tolerant. The first dose of atoxyl destroys all but the most resistant of the trypanosomes, and these multiply and again the most resistant survive the second dose, and thus a strain is eventually reached which is as resistant to the atoxyl as the tissues of the host. This change in the character of the trypanosomes depends on their asexual generation and is readily intelligible when it is realized that successive generations are really only fragments of the original resistant individuals. Whenever a sexual cycle is interposed, all the resistance to atoxyl is lost; and except from experimental inoculation the transmission of the trypanosoma diseases from one host directly to another must be a rare occurrence. A strain of trypanosomata which has developed tolerance for one of the organic arsenical preparations (arsenic-fast) is generally tolerant of the others also, but not in such high degree of inorganic arsenic.

The same tolerance may be developed in trypanosomata treated with other remedies; for example, some of the dyes are poisonous to certain species, but the same resistance is developed towards these. A strain which is arsenic-fast is as susceptible to these dyes as an untreated strain, and similarly a strain which is resistant to a dye (*e. g.*, trypan-red) shows no resistance to arsenic.

1. Cacodylates.

The earliest of the organic arsenic compounds to be used in medicine was sodium cacodylate, $(CH_3)_2AsO.ONa$, which is relatively feeble in action as it releases only small quantities of arsenic ion in the tissues. Most of the cacodylate is eliminated unchanged in the urine, some appears to be reduced to cacodyl, $(CH_3)_4As_2$, which is excreted in the breath and lends it an odor like garlic, while another small proportion is changed to the inorganic form and exercises the typical arsenic action. The amount which undergoes this transmutation is unknown and probably varies in different individuals and in different circumstances. Sodium cacodylate (Sodii Cacodylas, U. S. P.) is valueless

in syphilis. It is a white crystalline salt readily soluble in water. Dose, 0.06 G. (1 gr.). Another nearly related salt has been introduced as *Arrhenal* (CH_3-$AsO(ONa)_2$), and resembles cacodylate in action.

2. Atoxyl.

Atoxyl, or sodium arsanilate ($NH_2C_6H_4OAsOH.ONa$), was used extensively in trypanosome infections, in which it presented some advantages over the inorganic arsenic salts. It is absorbed rapidly and circulates in the blood longer than the arsenites, which are taken up by the tissues rapidly and thus can exert only a transient action on parasites living in the plasma. Atoxyl is excreted in the urine for the most part unchanged, but a small proportion undergoes decomposition and is believed to liberate the arsenious ions. Trypanosomes are not affected by atoxyl outside the body more than by many other substances, and there has been some discussion as to how its specific action arises in the body. Ehrlich holds that it is partially reduced in the tissues and that the product of reduction is the active trypanocide, and he has shown that such reduced bodies act very powerfully on trypanosomes in test-tube experiments; on the other hand, it has not been proved that this reduction occurs in the tissues. Others believe that the inorganic arsenic formed from atoxyl is the active agent, and there is no question that inorganic arsenic destroys the parasites both in the blood and in the test-tube; the more powerful action of the small quantities of arsenic liberated from atoxyl in the body may perhaps be explained by its being freed in the blood or in the interior of the parasite into which the atoxyl has penetrated, while inorganic arsenic leaves the blood very rapidly. Strong evidence in favor of the view that atoxyl acts in virtue of its liberating arsenic is offered by the observation that trypanosomes which have become resistant to atoxyl have also a low susceptibility to arsenic.

In a number of cases atoxyl has given rise to poisoning in man, the symptoms being dryness of the throat, headache, giddiness, fever, colic, vomiting and diarrhœa, nephritis, and paresis of the lower limbs; the most serious effects, however, are disturbances of vision, which may advance to total and permanent blindness. In animals, ataxia and tremors are seen, especially in the cat, and renal hæmorrhages in the dog. Blindness has also been induced experimentally in animals, and is found to arise from degeneration of the ganglion cells of the retina and later of the fibres of the optic nerve. It seems likely that these symptoms are the result of the arsenic liberated from the atoxyl, and that they are different from those ordinarily seen under arsenic, because the arsenic is liberated in unusual parts of the body, owing to the atoxyl penetrating where the inorganic forms fail to reach.

Atoxyl, sodium arsanilate ($C_6H_7NAsO_3Na$), is a white crystalline powder containing 27.2 per cent. of arsenic metal, soluble in six parts of water or about 125 parts of alcohol. It has a faint saline taste. Dose hypodermically, 0.1–0.3 G. ($1\frac{1}{2}$–5 grs.) per day in 10 per cent. solution.

A number of other arsenic compounds similar to atoxyl have been tested in trypanosomiasis and other diseases. Of these *Soamine* is practically identical with atoxyl, differing only in the amount of water of crystallization. *Arsacetin* is acetyl-atoxyl and resembles the parent substance closely in effects.

Atoxyl and its allies were introduced for the treatment of trypanosomiasis, in particular in sleeping sickness. And it still continues to hold a position for this purpose, for it is not yet established that the newer preparations are superior to it in trypanosomicidal power. But the hopes which were at first entertained that it would prove a cure for the disease are now dissipated; atoxyl appears to act efficiently on the parasites in the blood, but has less effect on those which have infected the lymph glands, and apparently does not reach those in the central nervous system in efficient concentrations. It clears the blood of the parasites, but the supply is constantly renewed from the foci in the nervous axis and eventually the parasites become resistant. In sleeping sickness atoxyl

may alleviate the symptoms and prolong life but a cure of the disease from its use is very rare. It was also proposed to use it in syphilis, but fortunately before it attained popularity, the frequency with which it causes blindness and other toxic effects was recognized and since then this group of compounds has been regarded as too dangerous to use.

3. Salvarsan or Arsphenamine.[1]

Salvarsan (p-dihydroxy-m-diamino-arsenobenzene), was introduced by Ehrlich for the treatment of syphilis and has enjoyed great popularity in the last few years. It differs from the organic arsenic compounds so far discussed in the fact that it contains arsenic in the triad form, and thus corresponds to the arsenites, while in atoxyl the arsenic is pentad and corresponds to the arsenates. Atoxyl itself appears to act only when it is reduced to triad arsenic in the body.

Neosalvarsan[2] or Neoarsphenamine also contains triad arsenic and resembles salvarsan in its action and uses.

Salvarsan was at first injected into the muscles in man, but it tended to be deposited locally and to give rise to pain, swelling and infiltration, and was absorbed only slowly. The intravenous administration was therefore adopted and has become the ordinary method, although some authorities hold that the intramuscular administration was abandoned prematurely.

When salvarsan is injected intravenously, there are as a general rule no symptoms elicited, but in individual cases effects varying from comparatively trivial disturbance to grave and even fatal issues have been met with.

Immediately after the injection there may be a feeling of faintness, headache, flushing and heat in the head and face, giddiness and nausea, general malaise, profuse sweating, dyspnœa, or restlessness and tremor; vomiting and diarrhœa have occurred sometimes. Some fever followed in the earlier cases, from the use of water contaminated with the proteins of killed bacteria. These early symptoms are rarely of serious import, and have become rarer, as experience in the use of the drug has grown and suitable precautions have been taken to prepare the patient for what should be regarded as of the nature of a surgical operation. The faintness and syncope are mainly due to fear of the injection and are rarely seen if the patient is in the recumbent position.

More alarming effects which are of the same nature as the flushing are the so-called "anaphylactoid" symptoms, marked by swelling of the lips and tongue, cyanosis and severe dyspnœa, urticarial and other skin eruptions, herpes labialis, stomatitis and albuminuria. When these symptoms arise in the later stages of a course of treatment, they suggest caution in the dosage and longer intervals between the injections.

Severe symptoms have arisen in rare cases several days after the injection, and fatalities have followed either from cerebral symptoms (encephalitis hæmorrhagica) culminating in convulsions, coma and death, or from skin affections (dermatitis exfoliata), or from jaundice developing into acute yellow atrophy of the liver. These fatalities have

[1] Other names introduced for this substance are *Kharsivan, Arsenobillon, Diarsenol, Arsenobenzol. Gallyl* is a compound of salvarsan and phosphoric acid.

[2] It is also known as *Novarsenobillon, Neodiarsenol*, etc.

become rarer in recent years and are probably not more frequent than those from chloroform anæsthesia. These symptoms arise in individual cases whatever preparation of salvarsan is employed and are not to be ascribed to any chemical impurity in it; it seems possible that they may be influenced by a variation in the aggregation of the particles of the drug in the blood and tissues through conditions which are at present unknown and uncontrollable. Many of the symptoms—notably the skin changes, the vomiting and diarrhœa, the capillary changes in the brain, which are associated with the cerebral symptoms—may be ascribed to the action of the simpler arsenic compounds derived from the salvarsan, for analogous results occur from inorganic arsenic.

Not infrequently swelling and œdema occur around the local manifestations of syphilis after salvarsan has been injected; for example when salvarsan is administered in syphilitic skin eruptions, the skin lesions swell up, and the secretion from ulcers is increased (Herxheimer). This may perhaps arise from the poisonous action of the proteins freed from the dead spirochætes.

In animals, the intravenous injection of salvarsan in large quantities causes a marked fall in systemic blood-pressure, which is stated to resemble that seen under arsenic in arising in part from direct action on the walls of the arterioles and capillaries, in part from central action; but other observers regard it as due to salvarsan weakening the heart. The pulmonary pressure in the dog is said to be increased from constriction of the arterioles, probably from obstruction from particles blocking the capillaries. In man a fall of blood-pressure sometimes follows the intravenous injection, but in other cases no change in the circulation is seen except a slight acceleration of the heart.

It is stated that in animals fatal encephalitis may be elicited by salvarsan, with hæmorrhages and thrombosis of the vessels; necrosis and other lesions of the liver have also been observed. In rabbits large doses are found to induce nephritis, which, like that induced by inorganic arsenic, arises from the changes in the general circulation and the fall in blood-pressure rather than from direct action on the kidney. It has also been shown (Alwens) that when the tricuspid valves of the heart have been injured in animals, they can be poisoned by smaller quantities of salvarsan than usual, and this has been attributed to the drug acting more strongly on the congested abdominal organs, especially the liver.

Salvarsan appears to have the same effect in accelerating the formation of red-blood cells as is possessed by the inorganic arsenic preparations.

Salvarsan is found to destroy cultures of spirochæte in the test-tube only in a concentration of about one in 1000, but its activity is greatly enhanced when it is digested with tissues; these presumably form inorganic arsenic compounds which are 30–40 times as toxic to the parasites.

Salvarsan is practically insoluble in water at the reaction of the blood and must circulate in colloidal form protected from aggregation by the proteins of the plasma. Neosalvarsan, soluble in water, has effects of

equal potency; but salvarsan remains longer in body, passing only slowly into true solution and thus acquiring a more prolonged and effective action.

Excretion.—The intramuscular or subcutaneous injection of salvarsan is followed by the appearance of arsenic in the urine and in smaller quantities in the stools; it generally disappears from the urine in ten to fourteen days while it may be found in the stools longer, but the duration depends on the extent to which it forms a local deposit in the muscles; it does not appear that any salvarsan is excreted unchanged in the urine after the intramuscular injection. When it is injected intravenously, salvarsan appears unchanged in the urine in five to ten minutes and persists in this form for five to six hours; thereafter arsenic is found in the urine for some days, apparently in the form of arsenites and arsenates. It is excreted in the stools in smaller proportions than in the urine, but for a longer time. It disappears from the blood at about the same time as from the excretions, but may be found in the liver, bone-marrow and kidney rather later; an arsenic reaction may be obtained from the liver and marrow as late as ten days after the intravenous injection in animals, but no arsenic is to be found in any of the organs after fifteen days.

It would thus appear that after its intravenous injection some salvarsan may be excreted in the urine unchanged, but after some hours inorganic arsenic compounds take its place and persist for several days. Arsenic corresponding to 50–75 per cent. of that injected has been regained from the urine; the fate of the remaining 25 per cent. is unknown. Some appears to be stored in the liver and bone marrow temporarily. Arsenic is not found in the cerebrospinal fluid after the intravenous injection of salvarsan.

After the injection of neosalvarsan, formaldehyde appears in the urine from the decomposition of the molecule, but this disappears in a few hours; the excretion of neosalvarsan otherwise resembles that of salvarsan.

Salvarsan, Arsphenamine, diamino-dihydroxyl-arsenobenzene hydrochloride, $HClNH_2OHC_6H_3As=AsC_6H_3OHNH_2HCl+2H_2O$, is a yellow, crystalline powder containing 31.5 per cent. of arsenic metal and readily oxidizing in the air; it is accordingly kept in vacuum tubes. It is readily soluble in water with an acid reaction. Dose, 0.3–0.6 G. (5–9 grs.) by intravenous or intramuscular injection. The salvarsan tube should not be opened until required. The contents are dissolved in sterilized saline (0.9 per cent.) and neutralized to litmus with normal caustic soda solution (0.1 c.c. of normal NaHO is required for each 0.1 G. of salvarsan); a precipitate is formed which redissolves on shaking. The solution should be very dilute for intravenous injection, at least 300 c.c. being used for 0.6 G. salvarsan and more commonly 500 c.c. or more. Great care must be taken that the solution is not injected into the tissues around the vein as it causes intense pain and induration.

Salvarsan is seldom injected into the muscles now as it causes great pain and is often deposited locally; when this method is used a strong solution (6–10 c.c.) is neutralized and is not diluted as for intravenous use.

Several metallic compounds of salvarsan have been suggested of which *Silver Salvarsan* is the best known; it is uncertain whether this is a chemical combination or a mixture of colloid silver and salvarsan. It is a brown powder readily soluble in water and contains no dissociable silver. Dose 0.1–0.3 G. injected at

intervals of four days or more. It has not been shown to have any advantages over salvarsan.

Neosalvarsan, Neoarsphenamine, $NH_2OHC_6H_3As=AsC_6H_3OHNHCH_2OSONa$, is a yellow crystalline powder readily oxidizing when exposed to the air and soluble in water with a neutral reaction; along with the arsenical compound it contains some inorganic sodium salts so that three parts of neosalvarsan are equivalent to two parts of salvarsan. Dose, 0.3–0.9 G. (5–15 grs.) by intravenous or intramuscular injection. The contents of a newly opened tube are dissolved in 25 c.c. freshly distilled water for each 0.15 G. neosalvarsan, and injected; the solution is neutral in reaction and thus requires no addition of alkali as in the case of salvarsan.

Salvarsan and neosalvarsan tend to oxidize very rapidly in the air with the formation of the poisonous paramidophenolarsenic oxide. They must be used immediately after solution and the solution should be made with freshly distilled water.

Therapeutic Uses.—Salvarsan was introduced by Ehrlich for the treatment of syphilis and has been succeeded by neosalvarsan, which has the advantage of being available with less manipulation, but is not generally admitted to be as efficient. At first it was hoped that a single injection of salvarsan would suffice to destroy the spirochæte of syphilis and realize the ideal of complete sterilization of the tissues as far as the virus of this disease was concerned. Although this hope has not been entirely fulfilled, the introduction of these arsenical compounds in the treatment of syphilis is a very important advance in medicine. Very frequently a single injection of salvarsan frees the blood from parasites within a few hours, and the Wassermann reaction, which is specific for syphilis, disappears; in a certain number of cases the disease is healed, but in others the reaction returns. Some weeks or months later the spirochætes can be found again and symptoms of secondary syphilis begin to appear. The first injection suffices to destroy the great mass of parasites, but a few survive and reinfect the tissues. The same tolerance develops as has already been discussed under the atoxyl treatment of trypanosomiasis, in which it was first observed. This acquired tolerance for salvarsan has been demonstrated in cultures of the spirochæte, which after treatment with increasing amounts for some weeks finally survived a concentration five times as great as that which proved fatal to controls.

It is now advised therefore that salvarsan or neosalvarsan should be injected repeatedly at intervals of one or two weeks, and that vigorous mercurial treatment should be initiated immediately after the first salvarsan injection and carried out as was customary before these new arsenicals were introduced. The treatment with arsenic compounds and mercury should be instituted as soon as the diagnosis is made, as the action of these specifics is much more efficient when the invasion of the parasites is only beginning and before they have reached inaccessible positions in the tissues. In the later stages, salvarsan is also very valuable, but when the parasites are distributed in the central nervous system it appears to be unable to reach them, and while those in the blood and organs may be destroyed, the symptoms of nervous sclerosis often show little improvement; even in these nervous (parasyphilitic) affections the process seems to be arrested or retarded in some cases, however.

Salvarsan differs from mercury in syphilis in its greater rapidity; the parasites disappear after mercury treatment just as after salvarsan, but a sterilizing concentration of mercury can be reached only after several days, and frequently entails more or less pronounced symptoms of mercurialism. The intravenous injection of salvarsan on the other hand acts within a few hours, but most of the drug is excreted within three days, and the surviving parasites multiply unrestrained. When salvarsan and mercury are used together, the immediate action of the one is obtained and is reinforced by the slower and prolonged action of the other. In addition, it seems likely that some parasites escape owing to their being only slightly susceptible to salvarsan (see p. 606), but the chances are small that the same individuals have a low susceptibility to salvarsan and also to mercury. The combined treatment with arsenic and mercury may thus be justified by theoretical considerations, and has been abundantly supported by clinical experience in the last few years.

Salvarsan is now used almost exclusively by intravenous injection, but there is some tendency to recur to the intramuscular use in the case of neosalvarsan, though it is unlikely that this will prove as efficient.

In the treatment of several other protozoal diseases, salvarsan has proved as successful as in that of syphilis. Thus in framboesia (yaws), recurrent fever, and Vincent's angina, it is remarkably efficient, and in spirillosis of the lower animals an equal success has followed its use. In malaria salvarsan is inferior to quinine, and in sleeping sickness it appears to be less useful than atoxyl. Neosalvarsan has been applied locally in 2 per cent. solution in syphilitic keratitis and in spirillar diseases of the mouth and teeth, with good results.

In a number of diseases in which inorganic arsenic has previously been used, salvarsan has been given as a substitute; thus pernicious anæmia, rheumatism and various skin diseases have been treated with it, but the results do not seem better than those obtained from the older arsenical preparations.

In cases of emaciation and malnutrition, the organic arsenic preparations are to be used with special care and in low doses, and in disease of the heart, vessels, or brain, and in very old and feeble persons or those suffering from nephritis or diabetes, salvarsan should not be employed except under special precautions. In such cases the patient should be prepared for the injection as if for an operation and should not be allowed to resume his ordinary occupation for several days; and the doses should be reduced in amount.

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PART III.

THE HEAVY METALS.

HEAVY METALS.

A LARGE number of important drugs belonging to the chemical series of heavy metals resemble each other so closely in their action in living organisms that they may be readily grouped together in a division of the pharmacological system. Some authors include in this series arsenic and antimony, but the former presents so many analogies to phosphorus in its effects that it is preferable to treat it apart from the heavy metals. Antimony is certainly as closely related to arsenic as to this group, and may be regarded as a connecting link between them.

The metals as such do not induce any symptoms except from their mechanical properties. Thus mercury may be swallowed in large quantities without causing mercurial poisoning, and silver or copper coins are equally devoid of effect as poisons. They are active only when they are capable of dissociation into ions of the metal or of an oxide. Thus potassium ferrocyanide does not cause any symptoms of iron poisoning when it is injected into a vein, because the iron passes through the body undissociated, and any effects are due to the ferrocyanide ion and not to the iron. In the same way compounds of the metals with ethyl and methyl, such as lead triethyl, have an action quite different from that of lead, as long as they remain undecomposed in the tissues, but eventually induce metallic poisoning, as they are broken up into bodies from which the lead or lead oxide ion can be dissociated.

The action of the heavy metals consists of two parts, the local effects induced at the point of application, and the general effects which follow the absorption of the poison into the blood and tissues. Either of these may be produced alone by suitable preparations and modes of administration, and they are to be regarded as entirely independent of each other.

The Local Action of the heavy metal series is due to their precipitating proteins in very dilute solutions; the nature of this action is not quite established, but it is considered by most authorities that no true chemical compound between the metal and the protein is formed, but that the precipitate is of the nature of an adsorption complex. Proteins are also thrown out of solution by salts of the alkalies and alkaline earths, but only when these are present in much higher concentration than is necessary in the case of the heavy metals; and the precipitate formed by the salts of the alkalies is reversible, that is, it can be redissolved by the addition of water.

When a salt of a heavy metal is added to a solution of egg albumin, or similar protein, a precipitate is formed consisting of proteins and a variable amount of the metal or its oxide, while free acid remains in solution. The precipitate is insoluble in water but is dissolved by neutral salts, including those of the heavy metals, so that the addition of more metallic salt may redissolve it; similarly the addition of more protein solution may redissolve by increasing the supply of neutral salts. The precipitate contains the metal in an insoluble form, and the latter may be detected by the ordinary reactions; thus the protein precipitate from iron salts is blackened by ammonium sulphide in the same way as ordinary iron.

On subjecting these precipitates to certain chemical manipulations, however, the metal seems to become more firmly attached to the protein, for ammonium sulphide acts on it much more slowly. The metal is then said to be masked, because its presence is not so readily detected as in ordinary combinations. Partially masked preparations have been formed artificially, but in the body the process is carried much further, for in many of their protein compounds the metals cannot be detected by any of the ordinary tests, however long the reagents may remain in contact with them, and their presence is recognized only when the protein is destroyed by heat or other similar agencies.

When a solution of a metallic salt comes in contact with a living tissue, such as the mucous membrane of the mouth or stomach, the same precipitation of protein and metal occurs and the acid is liberated; the local action appears to be determined by the combined effects of these factors. The more completely dissociated the ions of the salt are, the more rapid is the reaction with protein, and the more intense the local action. Thus the more readily ionized inorganic salts act more strongly than the organic ones, which are slowly dissociated, and these in turn are more liable to cause marked local changes than the double salts, which are dissociated with difficulty.[1] The activity of the acid liberated also varies with the extent to which it is dissociated into ions; it therefore exercises the same astringent or corrosive effects as if it had been applied uncombined, but its action may be modified by the presence of a layer of precipitate protecting the surface. Thus when a weak solution of lead acetate is applied to a mucous membrane, a precipitate is formed in the proteins lying on the surface, and protects the cells from the action of the very dilute acetic acid which is set at liberty. If a stronger solution be applied, however, the metallic precipitate extends into the cell, while the acetic acid, being more concentrated, exercises some irritant action. As the concentration increases, the deeper parts of the epithelial cells are coagulated, and at the same time the acid becomes more destructive, so that eventually the superficial layer of the epithelium is killed and the deeper layers are attacked. The acetate of lead may thus act as an astringent, covering a mucous surface with a protective pellicle of insoluble precipitate,

[1] *Pauli.* Biochem. Zeitschr., xli, p. 461.

or as an irritant, which induces an increase in the circulation of the part, a more rapid division of the cells and an effusion of liquid, or as a corrosive, involving the superficial layer of cells, and sometimes even the deeper ones, in its destructive effects.

When the nitrate of lead is applied, the astringent effect is much less evident, the irritant and corrosive more marked, because the salt is more readily dissociated and the reaction is therefore more rapid, and, in addition, the nitric acid is much more corrosive than acetic acid. The same metal attached to different acids may therefore induce very different effects, in the one case acting chiefly as an astringent, in the other as an irritant and corrosive.

The character of the metal which is carried down in the precipitate also influences the local effect; thus mercury is intensely poisonous and destroys the cells in which it is deposited, while lead is a less powerful poison and the cells may recover even if lead has been deposited on them.

In addition, salts which have a very strong affinity for water withdraw fluid from the cells, and thus act more strongly on them than others which have not this character; for example dried alum is much more destructive to the tissues with which it comes in contact than alum containing its ordinary water of crystallization.

The different metallic salts therefore vary in their local action within wide limits—from the formation of mildly astringent membranes to the production of widespread necrosis and destruction of tissue.

The most powerful corrosive salts of any metal are those which are most rapidly dissociated into ions, that is, the chlorides and nitrates, provided they are soluble. The sulphates are much less irritant, because they are less readily dissociated, and perhaps because the sulphuric acid may fail to penetrate the cells owing to its being less volatile and its anion having less permeating power than that of hydrochloric or nitric acid. (See page 105.) The iodides and bromides are generally regarded as less irritant than the chlorides, but are less frequently used and less well known.

The least corrosive of the salts of the metals are those formed with the slowly dissociated organic acids, such as the acetates, tartrates or citrates. When these are united with a metal which in itself is not a very active poison, such as lead, they are almost purely astringent. On the other hand, the acetate of silver or of mercury tends to be irritant and corrosive, from the poisonous action of these metals on the tissues. In any case, the acetates are less irritant than the corresponding chlorides and nitrates, provided these are equally soluble.

The local action also varies in the same salt of different metals. Lead is the most astringent of the metals ordinarily used in solution, while mercury salts have little or no astringent action, owing to their specific poisonous action on the cells. Iron and alum approach most nearly to lead, then copper, zinc and silver, and at a longer interval mercury and antimony.

It is impossible to arrange the metallic salts as either astringents or

irritants, because in every instance the effect varies with the concentration, and with many other features, such as the condition of the surface to which they are applied, and the quantity of protein with which they come in contact before they reach the living membrane.

Of the salts in common use, the most astringent are lead acetate and alum; the most irritant are the perchloride and the nitrate of mercury, the chlorides of zinc, copper, tin and antimony, while the chloride of iron, sulphates of copper, zinc, iron and manganese, the acetates of copper and zinc, and the nitrates of silver and lead are astringents when applied in very dilute solution, but tend to irritate and corrode in large quantities. In most cases the effects of the last group are made up of a mixture of astringent and irritant action.

The insoluble salts come into less intimate contact with the tissues, and have much less effect; but many of them are slowly taken up and may then act as irritants or astringents.

The insoluble preparations of mercury tend to irritate and corrode the surfaces to which they are applied, but the insoluble salts of the other metals are generally astringent. It is difficult to determine how far the so-called astringent and protective action of these insoluble substances is due to the formation of precipitates, and how far to their acting mechanically as protective coverings over irritated surfaces, but the latter factor is undoubtedly the more important in many instances.

If the metal is applied in the form of an "albuminate," that is, in the protein precipitate, the effects are the same as if it were used in any other insoluble form; for example, the "albuminate" of lead and most metals cause no irritation, but that of mercury acts as an irritant.

The precipitation induced by the astringents involves only the surface layer of cells, but the membrane formed protects the part from mehanical and chemical irritation, and thus lessens congestion and inflammation. Some authors maintain that the astringents contract the vessels by direct action on their coats, or lessen secretion by direct action on the secretory cells, but these statements are not satisfactorily established, and the changes may be the indirect results of the protection afforded to the surface cells. When irritation is induced, the vessels of course dilate, and congestion and exudation follow.

The salts of the heavy metals are often only slowly **Absorbed.** Mercury is again an exception, but even mercury does not induce general symptoms until many hours after its administration. The other metals given by the mouth pass through the alimentary canal for the most part unabsorbed. In recent years it has been disputed whether iron, manganese, copper and other metals are absorbed at all, but investigation with more accurate methods has shown that iron and manganese pass into the tissues from the alimentary tract, and it seems probable that a small proportion of most of the metals finds its way into the blood. At the same time there is no question that the great proportion of most of the metals passes through unabsorbed, and is devoid of any effect except from its local action. The form in which the metals are absorbed is quite unknown, but it is not unlikely that they are taken

up in insoluble forms by the leucocytes and thus carried into the tissues. When there is any lesion of the stomach and intestine, and particularly when the salt itself induces irritation and congestion, much more of the metal is taken up than by the normal epithelium. But even in the most favorable circumstances little of the metal is absorbed, and in acute poisoning the symptoms arise from the local irritation and corrosion and only to a smaller extent from the general action.

If the absorption of the metals is slow, their **Excretion** progresses even more gradually, and repeated administration leads to their accumulation in the tissues and thus to chronic poisoning. The metal seems to leave the blood very rapidly, and to become stored up in various organs, chiefly the liver, to a less extent the spleen, kidney, and bone marrow. While some of the metal is deposited in the liver and other organs, another part is excreted, for the most part along the alimentary tract. Thus it is found in the saliva and the secretions of the stomach and small intestine and, to a much larger extent, in the cæcum and in the large bowel; in some cases the excretion is limited to the large bowel, a strict line of demarcation being formed by the ileo-cæcal valve. A comparatively small amount escapes with the urine except in the case of mercury. Some metals have been detected in very small quantity in the milk, and there is reason to suppose that traces are eliminated by the other cutaneous secretions.

The **General Action** of the heavy metals in man is often elicited only by their prolonged ingestion, but it has been studied in animals by the intravenous or subcutaneous injection of such preparations as the double salts, which do not precipitate the proteins and slowly liberate the metal or its oxide. The ordinary salts cannot be used, because the precipitated albumin of the blood causes embolism, and this obscures the symptoms. The symptoms of acute metallic poisoning elicited thus in animals generally resemble fairly closely those of chronic poisoning in man.

Even when the heavy metals are injected into the blood in considerable quantity, the symptoms are often late in appearing, in the case of aluminium only after several days, so that the slowness of the absorption from the intestine is not the only factor in the delay in the onset of the intoxication.

The general symptoms of metallic poisoning, as distinguished from those due to the local action at the point of application, arise chiefly from the central nervous system, and from the excretory passages—the alimentary canal and the kidney. Metallic poisoning always induces disturbance of the **Stomach and Intestine**, manifested by loss of appetite, pain and discomfort in the abdomen, nausea, vomiting, and purging. In some cases no lesion of the canal is observed post mortem, but in the great majority congestion and swelling of the mucous membranes of the stomach and intestine is seen, or the whole surface may be covered by a diphtheritic membrane composed of necrosed cells and inflammatory exudate. Beneath this, hæmorrhages occur, and if the animal live long enough, ulcers are formed, so that the whole condition

can scarcely be distinguished from that of dysentery. Some metals act strongly on the mouth and induce reflex salivation, which is one of the earliest features of mercury poisoning. The lining membrane of the mouth becomes congested and inflamed, and numerous shallow ulcers are formed in it.

The heavy metals thus seem to have a specific action along the alimentary tract quite independent of the local action induced when they are swallowed, and apparently arising from their excretion along it. One or two metals, notably lead, cause constipation and colic when they are absorbed into the blood, but under certain circumstances they too induce purgation.

Another organ which suffers from the circulation of metals in the blood is the **Kidney**. Comparatively little of the metal is excreted in the urine, but it is found that most of this class act as diuretics in small quantities. Somewhat larger doses irritate the renal epithelium, and albumin appears in the urine, along with casts, and, in severe cases, blood cells and hæmoglobin. If this irritation of the secretory cells be long continued, it sets up a secondary inflammation of the interstitial tissue, and cirrhosis of the kidney results.

The **Circulation** is differently affected by different metals. The heart is often weakened only in the last stages, and it is impossible to determine how far its failure is due to direct action, and how far to the disorder of the nutrition. The blood-pressure invariably falls toward the fatal issue of the intoxication, and as a general rule, a slow fall is observed from the beginning. This fall in blood-pressure may doubtless be induced by different factors in the different forms of intoxication, but there is no question that it is partly due to the dilatation of the vessels of the intestines and stomach from the inflammation of these organs. In acute general poisoning in animals, many of the metals cause a great fall of blood-pressure, which is ascribed to their paralyzing the walls of the capillaries.

The general malnutrition from the gastro-intestinal action renders it impossible to determine whether the metals alter the metabolism of the body through directly affecting the cells, but it is not improbable that this is the case, for the loss of weight is often too rapid to be explained by the starvation alone.

The **Central Nervous System** is always affected more or less by the presence of the metals in the blood. As a general rule, the symptoms are a mixture of those of stimulation of certain divisions with those of paralysis of others. Several metals induce disturbance of the psychical centres, manifested in delirium, hallucinations and mania, or in stupor and coma. Convulsions of all forms indicate that the motor areas of the brain, the basal ganglia and the spinal cord are affected; thus epileptiform convulsions, chorea, clonic and tonic spasms occur from metallic poisoning. In several instances actual lesions of the brain cells have been shown to be caused by the ingestion of the metals. They often cause general weakness, or paresis of certain groups of muscles, and in addition to their specific action on the nervous centres, they may induce peripheral neuritis (lead).

Therapeutic Uses.—In therapeutics only mercury and iron are largely employed for their effects after absorption, while the others have a more or less extensive use for their local effects as astringents, irritants, caustics or styptics. Iron is not prescribed for its general action on the organs, but to supply the place of food-irons in the formation of hæmoglobin. Mercury is used for its specific effect in syphilis, and some of its preparations have been advised as diuretics. Not infrequently the local action of the heavy metals is supposed to be induced after absorption, and prescriptions are met with containing lead or iron which are intended to stay hæmorrhage from the lungs or from the kidneys. It ought to be recognized, however, that lead or iron is absorbed only in minute quantities, and that they have no predilection for the bleeding points. If they were capable of coagulating the blood after absorption, and thus stopping hæmorrhage, they would certainly do so in the portal circulation and would not be carried to the lungs or kidney before they acted. As a matter of fact, however, they never reach the blood except in forms in which they have no astringent or styptic action.

Many of the metallic salts are powerful disinfectants, partly no doubt from their coagulating the proteins of the microbes, but also from a specific poisonous action on them, which is quite distinct from their precipitating action. As a general rule the disinfectant power varies with the degree of dissociation of the salt, that is, with the number of metallic ions present in the solutions, although the undissociated molecule also seems to have some influence, and a salt which is dissociated with difficulty may in some instances make up for this drawback by the more intense toxicity of the metal.[1] The most widely used metallic antiseptics are the mercurial salts, in particular the perchloride, but silver is used as a disinfectant in some diseases and copper has been suggested.

Almost incredibly small quantities of some of the metals have been found to be rapidly fatal to some of the algæ, the bacteria, and the infusoria. Thus one part of the perchloride of mercury in one million parts of water kills spirogyra, one of the simpler algæ, and water distilled from copper vessels or in which small pieces of copper foil have been suspended[2] is rapidly destructive to many lower organisms. Silver is less active and lead still less so. The amount of copper in the solution is too small to be recognized by any chemical test. These results, which were first obtained by Naegeli, and which have been confirmed by other observers besides Israel and Klingmann, indicate that certain lower organisms are much more sensitive to the action of copper, and probably of other metals, than the more highly organized plants and animals.[3] Further examination of their effects as disinfectants in medicine and surgery is certainly desirable. Other curious effects on the growth of

[1] *Krönig u. Paul.* Ztschr. f. Hygiene, xxv, p. 1.

[2] *Israel u. Klingmann.* Virchows Arch., cxlvii, p. 293

[3] Some of the tissues of the higher animals are equally susceptible however, for Egmond (Pflüger's Arch., clxxx) states that the bundle of His of the mammalian heart is paralyzed by the immeasurable amount of copper which is liberated from a copper rod placed in contact with it.

bacteria have been observed by Bolton and Brown,[1] who found that a piece of metal placed on a culture of microbes in gelatin causes curious alternating zones of intense growth and of sterility. These observations have recently been extended by Thiele and Wolff,[2] who state that silver, mercury, or copper plates prevent the growth of microbes owing to minute traces of these metals being dissolved in the medium. Several other heavy metals—iron, lead, zinc, tin, gold, platinum and aluminum—proved devoid of action. A practical application of this bactericidal action of the metals has been made by the introduction of solutions of colloid forms of silver and mercury as antiseptics. Some of these colloid metals have proved destructive to simple organisms in extremely dilute solution, while in more concentrated forms they are inferior to the ordinary salts of the metals; there is every reason to believe that these colloid forms like the ordinary pure metals have no action until they are changed to dissociable salts, which exert their usual effects in the tissues.

I. ANTIMONY.

The preparations of antimony played a much more important rôle in therapeutics in the earlier part of last century than at the present time. In many respects they resemble arsenic in their effects, and may be looked upon as forming a link between it and the salts of the other heavy metals. The salt most commonly used is *tartar emetic*, or the double tartrate of antimony and potassium ($K(SbO)C_4H_4O_6$). As a double salt it is not readily dissociated and is therefore not so corrosive as the chloride, which is a powerful caustic when applied to the skin or the mucous membranes.

When rubbed on the **Skin**, however, tartar emetic causes redness, and a papular eruption, which later passes into vesicles and pustules. If the application be further persisted in, these pustules may become confluent and form small abscesses, and later cause extensive necrosis and ulceration of the skin. The points of origin of the papules are the openings of the cutaneous glands and the hair follicles. When injected hypodermically, tartar emetic causes intense and lasting pain, and very often suppuration and sloughing, which may involve the underlying muscles.

Symptoms.—Tartar emetic has a slight, acrid taste, and in very small quantities causes no symptoms, except some perspiration. In somewhat larger doses its ingestion is followed by nausea and vomiting, with very marked depression and the usual accompaniments of emesis, such as salivation, profuse perspiration and acceleration of the pulse (see Apomorphine, page 443). In antimonial poisoning the vomiting is violent and continuous, the ordinary contents of the stomach being first evacuated, and then a slimy mucous fluid, which may later contain blood. In some cases it is said that no gastric symptoms are observed,

[1] Transactions of the Assoc. of Amer. Physicians, xii, p. 488.

[2] Arch. f. Hygiene, xxxiv, p. 43. *Foa and Aggazotti.* Biochem. Ztschr., xix. *Moore and Hawk.* Biochem. Journ., iii, p. 313.

but these must be exceedingly rare. The vomiting is accompanied by profuse watery diarrhœa, resembling that of arsenical poisoning, and by great muscular weakness and collapse. The pulse may be somewhat accelerated at first, but is weak, and later becomes slow and irregular. The skin is cold and covered with clammy perspiration, and cyanosis of the face and extremities is generally marked. The respiration is slow and may be irregular, the voice weak and husky, the temperature is depressed, and the patient falls into a comatose condition, which deepens, until after a few weak convulsive movements the respiration ceases. The urine is sometimes increased in the beginning of the poisoning, but later may become scanty or entirely suppressed. It often contains albumin.

The minimum fatal dose of tartar emetic is doubtful, as the greater part of the poison is generally removed by vomiting. Recovery has been observed after very large quantities, while in other cases 0.1 G. (2 grs.) has proved fatal.

Chronic antimonial poisoning is very rare and difficult to diagnose. The symptoms are depression, headache, giddiness and confusion, drowsiness and indistinct sight. The appetite is bad, and the patient complains of heaviness, discomfort or pain in the region of the stomach, general weakness and exhaustion. Profuse diarrhœa may be present, rapid loss of flesh, albuminuria, and finally collapse. Pustular eruptions have been observed from the prolonged internal use of tartar emetic. There is some reason to suppose that printers occasionally suffer from antimony poisoning arising from the presence of antimony in the types.

Action.—Many of the symptoms of antimonial poisoning, the profuse perspiration, salivation and, to some extent at least, the collapse, are manifestly secondary to the **Emetic Action**, and the cause of the vomiting has, accordingly, been repeatedly investigated. The older writers regarded it as arising from some central action, but there can be no question that it is the result of local irritation of the stomach; small quantities cause vomiting without any obvious lesion, but larger doses induce hyperæmia and swelling of the gastric mucous membrane. Large quantities of antimony injected intravenously or subcutaneously also cause vomiting and purging, and this is apparently not due to its excretion into the stomach and bowel, for the movements occur in eviscerated animals; but much smaller quantities suffice to cause vomiting when given by the mouth.

In the stomach the antimony is slowly dissociated from the double salt and acts as an irritant; this liberation of the antimony ion may be aided by the acid reaction, but it also occurs when the reaction is rendered neutral, and in the intestine and skin where the reaction is not acid. It is more irritant than arsenic and is absorbed more slowly, so that its action remains confined to the stomach, and as the vomiting removes much the greater part of the poison, the intestine remains unharmed except when large quantities have been swallowed and the emesis is from any cause insufficient. In chronic poisoning ulceration of the small intestine is said to occur, especially around the solitary follicles and Peyer's patches.

The acceleration of the **Pulse** seen after tartar emetic is due to the emetic action and not to the absorption of the drug. When injected into a vein in animals, antimony acts directly on the cardiac muscle and causes a slow and weak pulse, although this is preceded in some cases by slight acceleration.

The **Blood-pressure** falls throughout the experiment, partly owing to the weakness of the heart, but chiefly owing to an action on the vascular mechanism similar to that described under arsenic.

The **Respiration** is often slightly accelerated at first, and may be shallow and irregular from the nausea; but in cases of poisoning it becomes slow and labored, and eventually ceases along with the heart. Marked congestion and œdema of the lungs is often found in fatal poisoning.

The **Central Nervous System** is depressed by antimony in the frog, while its effects in mammals are more obscure, for it is impossible to ascertain how far the changes are due to direct action and how far they are attributable to the disturbance of the circulation and the alimentary canal.

Many of the **Secretions** are increased by tartar emetic, such as the perspiration, the saliva and the mucous secretion of the respiratory tract. This is not due to any direct action on the glands, for the same effect is induced by anything which causes vomiting. (See Apomorphine, page 443). The urine is sometimes increased by antimony, at other times it is diminished or suppressed. This indicates that antimony, like most of the heavy metals, irritates the kidneys and thus increases their activity in small doses, while larger amounts cause inflammation and albuminuria or anuria; acute nephritis with hæmorrhages is often found in fatal poisoning, and in chronic poisoning the chief symptoms arise from the renal changes.

The irritant action of tartar emetic on the **Skin** when it is applied to it in ointment arises from the liberation of the antimony from the double salt; this apparently fails to penetrate through the horny epidermal layer and thus only causes irritation where it reaches the unprotected living cells at the mouths of the glands. The inflammation thus occurs at discrete points which may suppurate and form pustules.

Antimony is much less poisonous than arsenic to most of the protozoa, but is found to possess the same extraordinary affinity for certain pathogenic organisms, notably the trypanosomes of the blood, which it destroys in solutions as weak as one in 500,000.

The effects of antimony on the **Nutrition** are very imperfectly known; fatty degeneration of many organs is induced by its prolonged use, the nitrogen of the urine is found to be increased and the glycogen disappears from the liver. Very small quantities of antimony given repeatedly are said to increase the glycogen and fat of the liver, without apparently altering the nitrogen of the urine.

The fall in **Temperature** after antimony is often very considerable, amounting in animals to 6° C. in the course of a few hours. It is explained by the slowness of the circulation and by the general depression and collapse and profuse perspiration.

Antimony is **Absorbed** from the skin very slowly, and from the stomach and intestine. It passes into the tissues much more gradually than arsenic, however, and its action on the stomach can, therefore, be elicited without danger of its causing general symptoms. After absorption antimony is found in considerable quantity in the liver, which stores it up for some time. It is excreted into the stomach and intestine, in the urine, and, it is said, in the bile and milk. No such tolerance is acquired for antimony as is said to occur under arsenic.

The **Chloride of Antimony** ($SbCl_3$) differs from tartar emetic chiefly in being a violent corrosive, owing to the readiness with which the antimony ion is freed from it. The other compounds of antimony act like the double tartrate, except that most of them are slower in their effects. Stibine, or antimoniuretted hydrogen (SbH_3), differs entirely from arsine (AsH_3) in its action, which is, however, equally poisonous. It has very rarely been examined, except in an impure form, and the symptoms are imperfectly known.

Preparations.

Antimonii et Potassii Tartras (U. S. P.), Antimonium Tartaratum (B. P.), tartar emetic, tartrated antimony ($(KSbOC_4H_4O_6)_2 + H_2O$), forms colorless, transparent crystals, or a white granulated powder, without odor, and having a sweet, afterward disagreeable, metallic taste, soluble in 17 parts of cold water, insoluble in alcohol. Dose as an expectorant, 0.005 G. ($\frac{1}{12}$ gr.) B. P., expectorant, $\frac{1}{25}$–$\frac{1}{8}$ gr.; emetic, $\frac{1}{2}$–1 gr.

Vinum Antimoniale (B. P.), 4 per mille. 10–30 mins., diaphoretic; 2–4 fl. drs., emetic.

Tartar emetic is also contained in the compound syrup of squills U. S. P.

Therapeutic Uses.—Antimony is used to a much less extent in medicine than was formerly the case. In the seventeenth century it was prescribed so widely and was believed to do so much harm, that the graduates in medicine of Heidelberg were required to take an oath never to use it. At present it is used to a limited extent as an emetic, but is slow in action and induces greater depression and more prolonged nausea than the other drugs which are prescribed for this purpose, such as apomorphine, ipecacuanha, or sulphate of copper. It is therefore seldom used to evacuate the stomach in cases of poisoning or of foreign bodies in the stomach or œsophagus. Its expectorant action is taken advantage of in acute bronchitis in which the secretion of the bronchial mucous membrane is insufficient, but is of less value when the secretion is abundant. In commencing bronchitis tartar emetic is sometimes given until vomiting occurs, and then continued in smaller doses and at longer intervals.

It has recently been used in trypanosomiasis, especially in sleeping sickness, in which it has been administered by the mouth, intravenously and hypodermically. It is at least as efficient as the arsenic preparations, but its use is limited by the intense local action, which precludes its subcutaneous injection. Other protozoal diseases, such as syphilis, Bilharziasis, Kala azar, etc., have also been treated with it, and there is every probability that if a suitable combination could be formed it would equal or surpass the modern arsenical compounds in efficacy. The tartar emetic is injected intravenously in doses of 0.05 G., rising in a few days to 0.15 G. and repeated until 2 G. has been given, and this treatment has proved successful in many cases.

It is also used as a diaphoretic to some extent in the same doses as are prescribed as expectorants. Its use in acute fevers, lobar pneumonia and skin diseases has long been abandoned.

Tartar emetic was formerly used in ointment (one part to four) as a skin irritant, but its continued application led in several cases to diffuse subcutaneous abscess, and sometimes to necrosis of bone, so that the tartar emetic ointment has passed into desuetude.

In cases of **Antimonial Poisoning**, emetics are seldom required, but the stomach may be washed out by means of the stomach tube, if vomiting is not present, and a purge may be given to remove the poison in the bowel. Tannic acid, lime or magnesia may be used to precipitate the antimony in the stomach, and potassium hexatantalate has recently been advised for this purpose.

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II. MERCURY.

Mercury, one of the most powerful inorganic poisons, has been used in medicine for a long time and in a large variety of forms. Some differences are observed in the action of these, but all of them induce the same general results, the differences existing only in their local effects, and being due to the salts differing in solubility and dissociability. A soluble salt, such as the perchloride, comes into more intimate contact with the tissues, and therefore acts more powerfully locally and is also absorbed more rapidly and in larger amount than calomel, which is entirely insoluble in water. Both the local and the general effects of the perchloride are more marked than those of calomel, therefore, but when sufficient mercury in the form of calomel is absorbed into the tissues, the general effects are the same as if an equal quantity had been taken up as perchloride.

The corrosive action of the soluble mercury salts is doubtless due in part to their precipitation of the proteins, but in addition to this there is a specific toxic action on all living cells. It is unknown in what form mercury is absorbed and circulates in the blood, but there is no evidence that the insoluble preparations, such as calomel, are changed to the soluble perchloride before absorption; on the contrary, the mercury of the perchloride is precipitated in contact with proteins and must be taken up in this insoluble form. When mercury is injected hypodermically in an insoluble form, the leucocytes take it up and carry it off as they do any other foreign insoluble body, and it is quite possible that they may take it up in the same way from the alimentary canal. Less of the insoluble preparations are absorbed merely because they come into less intimate contact with the tissues than the soluble perchloride; but even the metal may be oxidized and absorbed when it is applied to the living surfaces or injected into the blood in a state of fine division. Thus the inhalation of mercury vapor by the lungs leads to general poisoning, often of a very malignant type, and mercury rubbed into very fine globules, and applied in ointment to the skin, passes into the gland ducts and along the roots of the hairs, and is absorbed into the tissues, in which it causes the typical mercurial effects.

Symptoms.—Acute Mercurial Poisoning occurs only from the use of soluble preparations, and in particular from the perchloride of mercury, or corrosive sublimate. Many cases have arisen from this poison being swallowed accidentally or with suicidal intent, or from its use as a disinfectant wash for large cavities. When corrosive sublimate is swallowed in poisonous quantity, the patient complains at once of the harsh metallic taste, which is followed by burning pain in the mouth, throat, and stomach. Nausea and vomiting set in very soon, and the vomited matter may contain shreds of mucous membrane and blood. Diarrhœa and violent tenesmus, with watery or bloody stools, often containing shreds of membrane, may be among the early symptoms, or may only occur after twenty-four hours. These symptoms from the alimentary canal are accompanied by collapse, with a small, thready, sometimes irregular, pulse, shallow, irregular, rapid respiration, cold, clammy skin, pinched features, and sunken eyes. The temperature is often subnormal, but sometimes fever is observed, although this is attributed by many to concurrent disease. The consciousness is usually unaffected, but in some cases somnolence, giddiness, or more rarely anxiety and restlessness have been observed. The urine is much diminished and complete anuria often occurs in a few hours. If the urine is not completely suppressed, it generally contains albumin, renal epithelium, casts and more rarely sugar. Death may occur within an hour from shock, but more frequently the patient survives several days or even one or two weeks, the symptoms of intestinal corrosion and of renal irritation continuing, until he finally sinks from exhaustion.

When acute poisoning occurs from the absorption of corrosive sublimate from wounds, the symptoms of corrosion of the mouth and stomach are absent at first, but the dysenteric symptoms and the renal inflammation are produced in the same way as when the poison is swallowed. Here again the patient may die within a few hours, but more frequently survives for several days, and in the latter case the symptoms toward the end partake of the character of chronic poisoning. In particular, salivation and stomatitis set in in the course of a few days. These also occur when the poison is swallowed, although they are more liable to be overlooked, from the cauterization produced in the mouth by the local action.

Chronic Poisoning.—A much more frequently observed form of poisoning is that induced by the prolonged medicinal use of mercury. It may arise from any of the preparations, and from any form of application, although some methods of administration are credited with being less liable to induce it than others. Thus inunction with mercurial ointment and the use of calomel internally are both more liable to cause the severer forms of stomatitis than is corrosive sublimate. A single hypodermic injection of an insoluble preparation may induce it in susceptible persons, because the mercury is only slowly absorbed, and passes into the tissues as gradually as if it were given by the mouth regularly for several days. This chronic poisoning, or **Mercurialism**, is due, not to the local action, but to the effects of the drug after ab-

sorption. It may follow the abuse of mercury in any case, but some individuals exhibit a special susceptibility from some unknown cause. Formerly it was believed that the earlier symptoms of mercurial poisoning had to be induced in the cure of syphilis, but in modern therapeutics every effort is made to avoid them. The first symptoms generally arise from the *mouth and throat,* the patient complaining of a metallic taste, and of a feeling of numbness or soreness of the tongue and gums. The breath has an unpleasant fœtid odor, the tongue is swollen and thickly coated, the gums are soft, swollen and often of a dark bluish-red or gray color and the flow of saliva is augmented. If the medication be continued, as was often done formerly, ulcers appear on the gums and on the sides of the tongue where it comes in contact with the teeth, especially if these are carious, and on the mucous membrane of the cheeks; the salivation increases and irritates the lips and the skin where it is exposed to the secretion. If the administration of mercury be still persisted in, the teeth become loose and fall out, gangrene of the gums, lips and throat, and necrosis of part or even of the whole jaw may follow. The milder forms of stomatitis and salivation are observed in a large proportion of cases of syphilis treated with mercury, according to some authors in 30 per cent. or more. It may be avoided, to some extent at least, by scrupulous cleanliness of the mouth and teeth, by attention to carious teeth, and by using a 2-4 per cent. solution of chlorate of potassium as a mouth wash.

The *stomach and intestine* also suffer in chronic mercury poisoning. The patient often complains of loss of appetite, and occasionally of a feeling of weight and discomfort in the stomach, nausea and vomiting, general weakness and loss of flesh. Colic and diarrhœa are frequently observed, or diarrhœa and constipation may alternate. These symptoms are naturally more liable to occur from the administration of mercury by the mouth than by other channels, as here the action after absorption is reinforced by the direct local effects. Some *fever* is sometimes noted, but this is secondary to the affection of the mouth, bowel or skin, and is not directly attributable to the mercury.

Occasionally *skin eruptions* are seen when mercury is given by the mouth, but much more frequently when it is applied to the skin. In the latter case they are not limited to the point of application, although they often begin from it and spread over a large surface of the body. They vary greatly in form, consisting of small reddish spots, large red erythematous surfaces, urticaria, or eczema, each of these occurring alone or in succession, and being usually followed by desquamation. The eruption generally lasts only one to three weeks, but in some cases has not entirely disappeared until three months after its appearance, and in others has returned repeatedly afterwards. It is said to have been induced occasionally by a single dose of calomel.

The *urine* is often somewhat increased, but may be decreased afterwards, and it not infrequently contains albumin, although the proportion of cases in which this occurs is much disputed, and the amount in the urine is generally very small. Glycosuria is much rarer in man,

but has been frequently observed in rabbits after prolonged treatment with mercury.

It is still a matter of doubt how far the *sexual organs* are involved in mercury poisoning. According to some authorities disturbances of the menstruation and even complete amenorrhœa have been observed, and abortion is also stated to have been caused by it.

A general condition of *cachexia* may be induced by these disorders, and is marked by pallor, anæmia, emaciation, weakness and restlessness, with a tendency to fainting and disturbed sleep. The pulse is small, weak and quick, and the patient often complains of breathlessness.

Affections of the *central nervous system* are rarely induced now by the abuse of mercury in therapeutics, but still occur in the case of workers in mercury mines, in mirror, barometer, thermometer, and other manufactories, in which mercury is used and its fumes are inhaled by the workmen for prolonged periods. One of these affections is the mercurial *erethism*, a condition of abnormal irritability, timidity or shyness, accompanied by great muscular weakness, and sometimes developing into sleeplessness, delirium and transitory hallucinations. Another well-known form is the mercurial *tremor*, which affects the hands and arms first, later the legs, and sometimes extends over all the muscles of the body. Shooting pains along the nerves or in the joints are sometimes complained of, circumscribed areas of partial anæsthesia, amblyopia, anosmia or deafness have been described, and in some cases localized paralysis of the muscles of the arm or leg has been induced.

The symptoms of mercurial poisoning, both acute and chronic, in animals, resemble those in man so closely that it is unnecessary to describe them further.

Action.—Lower Forms of Life.—Mercury is destructive to living matter wherever it comes in contact with it in sufficient concentration. This poisonous action is naturally much more evident when soluble preparations are used than when the oxides or calomel is in question. Thus corrosive sublimate in a solution of one part in 50,000 destroys infusoria in some 20 minutes, and even one part in one million kills algæ in the course of a few days. The effects of mercury in syphilis arise from its affecting the specific organism in a similar way, for mercury in a dilution of one in 200,000 destroys spirochætes in the test-tube. The exact amount of mercury present in an active form in the tissues cannot be estimated, but it probably is effective in very great dilution in cases of syphilis. Here, as in the case of other specifics (quinine, arsenic, antimony, etc.), mercury seems to have a stronger affinity for the parasite than for the tissues of the host, and even than for nearly related organisms; for mercury has little effect in malaria or trypanosomiasis, that is, it does not injure the organisms of these diseases in the same degree as it does that of syphilis. The bacteria are somewhat more resistant than these forms, but corrosive sublimate is said to delay the development of some of these in a solution of one

part in one million, and the anthrax bacillus fails to grow in blood which contains one part in 8,000. A solution of one part in one thousand is generally regarded as capable of disinfecting fluids completely in the course of a few hours, but there is no question that the germicidal power of corrosive sublimate has been much overestimated. Thus Geppert found that the spores of anthrax could be exposed to the action of a 1 per cent. solution for many hours and still develop as soon as the mercury was entirely removed. There is no doubt, however, that corrosive sublimate and the other soluble salts of mercury are among the most powerful antiseptics at present available. The insoluble preparations are less poisonous, owing to the difficulty in bringing them into intimate contact with the microbes.

In the **Higher Animals and in Man** the same destructive effects are induced by the mercury preparations. The corrosion of the mouth, throat and stomach when the perchloride is swallowed, has already been mentioned. When it is applied to the other mucous membranes, similar effects are obtained, and when it is injected hypodermically, even in dilute solution, it induces intense pain, swelling and inflammation, which is rarely followed by suppuration, but which may result in the formation of cicatrices. Stronger solutions injected into animals often cause the formation of cheesy abscesses, and even dry necrosis of the skin and underlying tissue. The hypodermic or intramuscular injection of insoluble preparations is more liable to cause abscess formation, because the mercury is slowly absorbed and has therefore more time to induce its irritant effects.

When solutions of corrosive sublimate are applied to the skin, they cause a feeling of numbness very often; but when very strong solutions come in contact with tender parts of the skin, and in particular, when the salt itself is allowed to lie in contact with it for any length of time, deep corrosion, necrosis, and sloughing may follow. Even the insoluble preparations are liable to set up irritation when they are rubbed into the skin, especially if there is any preëxisting tendency to cutaneous eruption.

After absorption, mercury acts more especially on the alimentary tract and on the kidneys, although other organs are not exempt from its effects.

The Salivation and Stomatitis, which are so frequently seen under mercurial medication, are obviously not due to the local action of the drug on its way to the stomach, for they occur equally readily when it is applied by hypodermic injection or by inunction. It is still a matter of doubt whether the salivation arises from the direct action of the mercury on the secretory apparatus, or reflexly from the irritation of the mouth, though it often precedes any obvious lesion. The saliva is sometimes excreted in enormous amounts, many litres of it being poured out in the course of twenty-four hours. It contains mercury, and has therefore a metallic taste, and tends to irritate the lips and skin where it comes in contact with them. In extreme cases it leads to sleeplessness from its accumulating in the back of the throat and

awakening the patient with a feeling of suffocation. The stomatitis is due to the excretion of mercury by the glands of the mouth and throat. The irritation caused by the metal leads to excoriations, and these to the formation of ulcers, particularly where microbes are present in large numbers, as around carious teeth. The necrosis of the jaws arises from these ulcers penetrating to the bone and setting up periostitis, for mercury in itself has no specific action on the bone such as has been mentioned under phosphorus.

Mercury has less direct effect on the **Stomach,** though congestion and even small hæmorrhages in cases of poisoning indicate that it is not entirely immune; the loss of appetite and malnutrition in chronic poisoning are ascribed to the presence of mercury in the saliva rather than to its affecting the gastric functions directly. In the **Intestine,** on the other hand, mercury is excreted in larger amount, and induces very distinct lesions. The parts affected are the cæcum and colon, while the small intestine often escapes almost entirely. The action of mercury is evidenced by hyperæmia, redness and swelling of the mucous membrane, which later develop into necrotic surfaces and ulcers along the folds; these lend it an appearance almost indistinguishable from that of chronic dysentery and may eventually end in perforation. The symptoms from the intestine are in accordance with the lesions, consisting in constant purging with very fluid, sometimes rice-water, stools, intense pain and tenesmus, blood and fragments of mucous membrane in the fæces.

The **Purgative Action** of mercury is discussed on page 103.

Mercury has no such powerful effect on the **Unorganized** ferments of digestion as it has upon the microbes, for though large amounts of the soluble preparations precipitate the pepsin in artificial digestion experiments, smaller quantities have little effect. Calomel has no action on the digestive ferments, but may retard the putrefaction in the intestine, and thus limit the decomposition of the food. Its antiseptic action is aided by the increased peristalsis which follows its use, and which removes the decomposing mass from the canal.

The **Kidney** is excited by mercury, a moderate dose of calomel inducing marked diuresis, particularly in cases in which there is a large accumulation of fluid in the body, as in dropsy from heart disease. When purging follows the administration of the mercurial, less diuretic effect is observed. In normal individuals and in animals the diuretic action is generally weaker; the kidney is affected directly and not through changes in the circulation.

In acute mercurial poisoning, when death does not follow in the course of a few hours, anuria is often observed with inflammation and necrosis of the epithelium of the tubules. The whole organ is congested and the glomeruli are in a state of acute inflammation, but the necrosed tubules are the most prominent feature. Very generally in the rabbit, less often in the dog and in man, these are filled with a deposit of phosphate of calcium, which is thrown out in the necrosed cells, and as these break up, passes into the tubules. It may be remarked in passing that

several other poisons, such as bismuth, and aloin, occasionally induce this deposit of lime in the kidneys.

This renal necrosis occurs chiefly in corrosive sublimate poisoning, as the more slowly absorbed, insoluble preparations apparently do not often accumulate in sufficient quantity in the blood to induce such severe effects. At the same time, albumin or casts are often observed in the urine from the treatment of syphilitic patients with mercury in any form, although it is stated that this is less liable to occur when soluble preparations are injected hypodermically than after inunction or the use of insoluble salts subcutaneously. The more marked the action on the intestine, the less destruction of the kidney is observed in cases of severe poisoning.

The lime deposited in the kidney has suggested the idea that mercury causes the absorption of the calcium in the **Bones** through a specific action on them, but the lime deposited in the kidney is drawn from that normally circulating in the blood; in necrosed tissue from other causes lime is very often deposited, although not so rapidly as in mercury poisoning. Large doses given repeatedly lead to an increase in the size and number of the vessels of the bone-marrow, and the fat cells atrophy rapidly; later gelatinous degeneration follows and the cellular elements of the marrow disappear.

Mercury seems to have comparatively little direct action on the **Circulation** in cases of poisoning, and most of the changes in the pulse are to be ascribed rather to the shock and collapse, or in chronic poisoning to the cachexia and malnutrition, than to any direct effects on the heart and vessels; in some cases of acute poisoning, however, patches of fatty degeneration have been found in the heart. In the frog large doses of soluble salts slow and weaken the heart, and mercury salts injected into the bloodvessels of mammals have been found to cause a sudden descent of the blood-pressure and paralysis of the heart. Subcutaneously injected into animals, the soluble salts reduce the blood-pressure more gradually, but at the end a very sudden descent to zero occurs. The action is in part on the heart, in part on the vessels (capillary poisoning).

The **Respiration** is also only affected indirectly. In chronic mercury poisoning marked breathlessness is sometimes observed and was ascribed by Kussmaul to the general muscular weakness but may arise from acid being developed in the tissues.

The action of mercury on the **Nervous System** is very obscure. In acute poisoning the intellect often remains clear to the end, and no symptoms pointing to any direct affection of the central nervous system are observed. In chronic poisoning, however, the higher centres are undoubtedly involved in the effects, as is shown by the erethism and occasional hallucinations. The tremor is also of cerebral origin probably, though this is not yet certain, and the general muscular weakness is not due to the peripheral muscles and nerves being affected, but to the alterations in the centres. The paralysis sometimes observed in the arms or legs in workers in mercury, and the areas of partial anæsthesia and the pains in joints probably arise from peripheral neuritis. In some cases, especially where the tremor is marked, the reflex excitability of the spinal cord has been found to be exaggerated but it is generally unaffected. The muscles do not seem to be acted on directly in either acute or chronic poisoning in man, and even when

paralysis is developed, they maintain their irritability and do not atrophy.

A good deal of interest has been manifested in the question whether mercury affects the **Nutrition** in any way except through its action on the alimentary canal. It is sometimes stated that the protein metabolism is accelerated, but the subject is a difficult one to investigate, for when any save the smallest doses are given, the kidney and bowel are involved in the effects, and the prolonged use of mercury is restricted to experiments on animals and on syphilitics. The cachexia of chronic poisoning may be due in part to a specific action on the metabolism, but it is impossible to determine this point, because the alterations in the alimentary tract are in themselves sufficient to cause such symptoms.

Changes in the **Blood Corpuscles** have been observed under mercurial treatment in a number of instances, but there is as yet no general agreement as to wherein these consist, and it seems not unlikely that the blood reaction in health is different from that in syphilis and that it may vary in the successive stages of the disease. In health the red corpuscles and the hæmoglobin are said to be augmented at first but afterward diminished, while in syphilis a sharp fall in the amount of hæmoglobin is succeeded by an increase to beyond that present before the treatment. Kuperwasser states that in healthy persons mercury increases the number of newly formed leucocytes but that this is more than counterbalanced by the fall in the older cells; in syphilis he found fewer recently formed leucocytes and more mature ones after mercury.

Mercury has no effect on the **Temperature** in itself, but when stomatitis or skin eruptions are developed, some fever generally accompanies them, while in collapse the temperature may fall several degrees below the normal.

Distribution.—After its prolonged use mercury is found in almost every organ of the body, but larger quantities are found in the kidney, intestinal wall and especially in the liver. In cases of acute poisoning through absorption from the subcutaneous tissue or from wounded surfaces, the distribution is the same. The statement that mercury is stored up in large quantities in the bones has not been confirmed by the more recent investigators, but traces are found here, as in the muscles, brain, lungs, intestine, and spleen.

Mercury is **Eliminated** by almost all the excretory organs, but most largely by the intestine and kidney. It has been found in small quantities in the perspiration, milk, saliva, sweat, gastric juice and bile, and has been shown to pass to the fœtus in utero through the placental circulation. The excretion in the urine begins within an hour when mercury is injected intravenously, but more slowly by the ordinary methods of administration; for example, after inunction, none may be found for twenty-four hours. The quantity eliminated daily rises slowly during the treatment and then falls gradually. The excretion is very slow and varies according to the method of administration; there is no question however, that after the usual methods of adminis-

tration in syphilis mercury is found in the urine for months and in some cases for years after the last dose. No accurate estimation of the mercury excreted in the fæces has been made, but it is believed that less is excreted here than in the urine at first, but that later the greater part may pass out by the intestine. The administration of potassium iodide does not accelerate the elimination of mercury. In the urine the mercury probably exists for the most part in the form of a salt, although some of it may be in organic combination.

Mercury forms very poisonous compounds with methyl and ethyl, which are apparently slowly decomposed in the organism to ordinary forms, and which have given rise to fatal poisoning in two cases, the symptoms making their appearance only long after the ingestion.[1]

Therapeutic Uses.—The chief purpose for which mercury is used internally is the treatment of **Syphilis.** Its curative effects in this disease are due to its specific destructive action on the spirochæte pallidum, the organism of syphilis. Long a subject of discussion, its usefulness in this infection is now acknowledged by all who have studied the subject. It is true that mild cases sometimes recover without the use of mercury, but even these run a shorter course if mercury is administered. And in many others, in which the symptoms show no signs of abating under hygienic measures, mercury causes a rapid and permanent improvement. A certain number of relapses undoubtedly occur after the mercurial treatment has been left off, but it seems probable that many of these would not have had even temporary relief without mercury. In a certain proportion of malignant forms mercury is unable to arrest the progress of the disease. And when the organism has invaded the central nervous system, mercury does not seem to be able to reach it, for no improvement is obtained from its use in tabes or in the general paralysis of the insane.

The effects of mercury in syphilis present many analogies to that of arsenic and antimony in trypanosomiasis; in each a protozoal parasite in the tissues is in some cases destroyed by the specific remedy, and this is fortunately often complete in syphilis; but in other cases a relapse occurs from some of the organisms surviving the first treatment. In the case of the trypanosomes these survivors are more resistant to the specific than the original infection, and this appears to hold for the organisms of syphilis also; in test-tube cultures the spirochæte acquires a high tolerance for mercury if it is added to the culture fluid in gradually increasing amounts.

The recent introduction of the organic arsenic compounds has not led to the mercurial treatment being abandoned, for it is found necessary to combine the action of both parasiticides to obtain the best results in the treatment of syphilis. The injection of salvarsan ought to be followed by a vigorous use of mercury until the specific Wassermann reaction disappears and remains absent.

[1] *Hepp.* Arch. f. exp. Path. u. Pharm., xxiii, p. 91.

The study of the arsenic treatment seems to have finally determined a long debated question, whether mercury should be exhibited in the primary stage of syphilis. The danger of a widespread infection, possibly involving the central nervous system, is now recognized to be so great that no delay is permissible; vigorous treatment with salvarsan and mercury should be instituted as soon as the disease is diagnosed and should be continued as long as there is any risk of a relapse. The treatment with mercury is not so heroic as a century ago, and all are agreed that it ought not to be allowed to induce any but the earliest symptoms of chronic poisoning. In tertiary syphilis mercury is generally associated with the iodides, as it is found that the resolution of the new-grown tissue by the latter facilitates the destruction of the spirochæte by the mercury. In animals mercury in large doses has been found to prevent infection with syphilis.

Mercury has been used in syphilis in a large number of forms, and of late years many new preparations and new methods of administration have been proposed. Mercury cures syphilis by destroying the organism, and this object is to be attained by introducing enough of the metal to act on the spirochæte without inducing symptoms from its action on the tissues. The estimation of the metal absorbed by the different forms of treatment is thus of much interest, and a fairly accurate idea of the amount absorbed appears to be given by that excreted. The best clinical results appear to follow from a rapid absorption and prolonged excretion, as, if the stay of the mercury in the tissues is short, relapses are liable to occur. Formerly mercury was given *by the mouth* or by inunction, and apart from the special clinics and the syphilologists, the internal treatment is still the most popular one. The preparations generally used for internal administration are corrosive sublimate, calomel, or the metallic preparations —blue pill and gray powder—the last being used most widely in England. Calomel and the metallic preparations are, however, very liable to induce diarrhœa, from their being insoluble and thus passing far down the intestine before being absorbed, and opium is therefore often prescribed along with them. Calomel is also credited with causing salivation and stomatitis more readily than the other preparations, perhaps because it is more difficult to gauge how much of it is absorbed than in the case of the soluble perchloride. Large amounts of mercury have been shown to be absorbed, when calomel and other salts are taken, but the concentration in the blood appears to vary more irregularly from day to day than when other methods are employed. And mercury administered by the mouth is in all cases more liable to derange the digestion than when administered by other channels, and on the whole is less certain and less satisfactory in its results.

Inunction was introduced to avoid the disturbance of the stomach and intestine caused by the local action of the mercury, while that due to its excretion along the alimentary tract remained unchanged. Mercury ointment is rubbed into the skin and is absorbed in part from the ducts of the glands and in part by the lungs as vapor. The absorption

is slower than by internal administration, but is more regular and lasts longer and there is less disturbance of digestion. The objection to the method is that it is inconvenient and uncleanly, and that it is even less possible to estimate the amount of mercury actually absorbed than when it is given by the mouth. Instead of mercury ointment being rubbed into the skin, one of the plasters, or lint containing mercurial ointment (Weylander), may be applied to it, permitting of the continuous absorption of small quantities by the skin and by inhalation of the vapor. Or a mild effect may be induced by mercury in a state of fine division being carried in a bag in the clothing.

In 1867, Lewin introduced the *hypodermic or intramuscular injection* of a dilute solution of corrosive sublimate. The advantages of the method are the avoidance of digestive disturbance, which is shared by the inunction method, its cleanliness, the more accurate estimation of the amount of mercury actually administered, and the greater quickness of action. The absorption is very rapid, mercury appearing in the urine in the course of an hour, but the maximum is soon reached and much of the metal is eliminated in two or three days. Its chief disadvantage is the pain caused by the injection, which has to be repeated daily; some inflammation and swelling follow immediately, but no suppuration, when ordinary care is taken; but the pain is very intense and persistent and many patients refuse to continue the treatment. Salivation is said to follow this method more seldom than any other, and relief from the secondary syphilitic symptoms is gained sooner. Various other soluble preparations have been advocated, but have not been used widely and have now been abandoned as offering no great advantages over the perchloride; and the perchloride itself is comparatively seldom injected at present.

Instead of the soluble preparations of mercury, which necessitate the painful injections being repeated daily, *insoluble salts* have been injected into the muscles with the idea that these being slowly dissolved and absorbed from the seat of injection, a quantity sufficient for several days may thus be given at one time. The immediate pain is less than from perchloride injections, but, as solution takes place, and the mercury attacks the tissues, the part becomes extremely painful, swollen, and inflamed. Suppuration and even gangrene have been developed in a very considerable number of cases, and in others severe or fatal mercury poisoning has been observed. The advantages of the method are that the physician has not to visit the patient every day, and that the injection need only be made once, or at most twice a week. On the other hand, the local lesions are often very severe, and the amount of mercury absorbed cannot be controlled in any way. It has the advantage over the administration per os that the digestion is not so liable to be disturbed. In spite of its drawbacks, this method has gained a wide popularity and is considered more certain than any of the others except the injection of perchloride, which shares its disadvantages. The amount of mercury in the circulation (as measured by that excreted) is subject to less variation than is the case with other

methods except inunction, which is much slower in effect. The preparations most commonly used are calomel suspended in salt solution or in liquid paraffin, metallic mercury in very fine division suspended in liquid paraffin, the salicylates and the thymol-acetate. The oxides have also been proposed, and many other preparations have received a trial by this method.

Other methods of introducing mercury into the tissues are more rarely employed. The *intravenous injection* of the perchloride has been suggested for the treatment of cases in which there is urgent haste, but is scarcely to be recommended in ordinary infections, as there is danger of embolism; and while the blood contains a large quantity for a short time, the concentration falls very rapidly from the metal being eliminated.

Suppositories of mercury have been used to some extent and are said to disturb the digestion less than the administration per os.

Mercury *fumigations* have also been practised to a limited extent, the vapor of mercury being freed by heating calomel or the sulphide. The patient sits in a wooden tent up to his neck, and the mercury deposited on the skin is absorbed. The method is very cumbrous and the quantity of mercury taken up cannot be controlled.

The **Other Protozoal Infections** are not so amenable to mercurial treatment as syphilis, and it has proved of no value in malaria or trypanosomiasis. Some spirillar infections in animals are said to react to mercury in the same way as syphilis, however.

Mercury was recommended by Hamilton in the beginning of the last century in the treatment of **Acute Febrile Affections**, and the greatest abuse unquestionably prevailed in the earlier decades. Later its sphere of usefulness was restricted to the treatment of inflammation of the serous membranes—pleurisy, meningitis, pericarditis, peritonitis—but its usefulness in these conditions has never been established and its employment is now more limited; in acute iritis it is still used widely. In these cases it is always administered by the mouth in the form of calomel, blue pill, or gray powder.

As a **Purgative** mercury is very frequently prescribed in "biliousness" and in putrefactive diarrhœa. (See page 103.).

Calomel and other mercurials have long been known to be of value in cases of **Dropsy**. The best preparation is calomel, given in 0.2 G. (3 grs.) doses three times a day or in 0.1 G. (2 grs.) doses five times a day. It is of great value in certain cases of cardiac dropsy, but is less reliable in the accumulations of fluid met with in hepatic or renal disease, although here too its administration is sometimes followed by the rapid excretion of the fluid. It does not seem to be contraindicated in chronic nephritis, although its action has to be carefully controlled. It has no effect in removing the exudations of acute inflammation such as pleurisy.

Mercury is used **Externally** as a **Disinfectant** wash in surgical operations, chiefly in the form of the perchloride, but also as the cyanide and oxycyanide. (See page 143.).

Numerous ointments have been applied externally in the treatment

of **Skin Diseases**, particularly those of a parasitic nature, such as itch, and in condylomata, ulcers, and skin diseases of syphilitic origin. These preparations combine a disinfectant with a more or less irritant action, and unlike carbolic acid and its allies, are equally powerful antiseptics in ointments and in water. The least irritant of the pharmacopœial ointments is the mercury ointment; then the oleate, yellow oxide, red oxide and ammoniated mercury follow in order, while citrine ointment is much more irritant and corrosive. Other external applications are the plasters and the black and yellow wash. Ointments containing calomel, corrosive sublimate and other preparations are sometimes prescribed, or calomel may be used as a dusting powder in syphilitic ulcers and as a prophylactic against infection. The mercury ointments are frequently applied to the eye, the milder ones as antiseptics and slight irritants, citrine ointment to destroy granulations.

Mercurial ointments are sometimes employed to promote the absorption of subcutaneous effusions and to reduce swellings. They are not superior to other irritants for this purpose, however, and have the disadvantage of permitting the absorption of a dangerous poison.

The nitrate of mercury and its ointment (citrine) are sometimes used as caustics for application to the os uteri, condylomata, and elsewhere.

Mercury treatment is **Contraindicated**, or requires special caution in cases of profound cachexia, weakness or anæmia, unless these arise from syphilis. Where the digestion is weak, it ought to be avoided if possible, and in cases of tuberculosis there is always the danger that the disturbance of the digestion may accelerate the course of the disease. In severe nephritis it is also to be used with caution, although it is beneficial in some cases, and although some authorities deny that it is injurious even when it has no diuretic action. In pregnancy mercury is not absolutely contraindicated, at any rate up to the sixth month. Later it is liable to injure the patient by its action on the digestion, and in some cases has induced abortion; the child may also suffer from mercurial poisoning. Mercurial ointments or dusting powders have to be used with care when iodides are being administered internally, as the iodide of mercury may be formed and may cause violent corrosion. Thus in the eye, severe effects have been induced by the application of calomel to the cornea while iodide of potassium was being given.

In cases of **Acute Corrosive Poisoning**, the indications are the evacuation of the stomach, preferably by the stomach tube. Tannic acid, or eggs, milk and other albuminous substances may be given to precipitate the metal and protect the mucous membrane. The treatment of the later symptoms is the same as that of the chronic form.

In **Chronic Poisoning** the salivation and stomatitis are treated by the use of potassium chlorate solution as a mouth wash, and its free application during mercurial treatment, along with careful brushing of the teeth, is believed by most physicians to hinder the onset of the symptoms. Tannic acid solution is also recommended as a mouth wash.

The diarrhœa may be treated with opium, the other symptoms on general principles. In any case the drug ought to be abandoned, or the dose much reduced as soon as the salivation becomes marked. Iodide of potassium and hot baths or sulphur baths are often advised in chronic poisoning with the view of accelerating the elimination of the metal, but careful estimations have shown that they have no such effect.

Preparations.

Hydrargyri Chloridum Corrosivum (U. S. P.), Hydrargyri Perchloridum (B. P.), corrosive sublimate ($HgCl_2$) forms heavy, colorless crystals without odor, but possessing an acrid, metallic taste, soluble in 16 parts of cold water, in 2 parts of boiling water, in 3 parts of alcohol Dose, 0.003 G. ($\frac{1}{20}$ gr.); B. P., $\frac{1}{32}$–$\frac{1}{16}$ gr.

Liquor Hydrargyri Perchloridi (B. P.) (0.1 per cent.), $\frac{1}{2}$–1 fl. dr.

Corrosive sublimate is one of the most irritant preparations and is rapidly absorbed. It is used internally in syphilis in 0.1 per cent. solution and is also injected intramuscularly in 0.6 per cent. solution, 2 c.c. (30 mins.) daily. This solution is often made up with 6 per cent. of sodium chloride or urea. Perchloride of mercury is less liable to induce salivation, but disturbs the digestion more than other preparations when given internally, while its intramuscular injection is exceedingly painful. It has induced fatal poisoning in the dose of 0.18 G. (3 grs.), taken by the mouth, but other cases have recovered from much larger quantities. It is stated that opium eaters can take enormous quantities without evil effects.

It is used extensively in surgery as an antiseptic solution (1 in 2,000–4,000), to disinfect the hands, wounds, etc., but is irritant to delicate tissues, such as the peritoneum, and corrodes steel instruments. The U. S. P. prescribes tablets (*Toxitabellæ Hydrargyri Chloridi Corrosivi*) each containing 0.5 G. of corrosive sublimate to make up these solutions. It is also used in the form of a soap and to impregnate bandages, cotton-wool, gauze, catgut, and silk. It preserves its antiseptic action in oils and ointments. It has been used to a limited extent in skin diseases in solution, in baths, or in ointment, as a local application in diphtheria, and as an intestinal antiseptic in putrefactive diarrhœa, typhoid fever and cholera.

Hydrargyri Iodidum Rubrum (U. S. P., B. P.), red iodide of mercury, biniodide of mercury (HgI_2), a scarlet-red amorphous powder, tasteless and odorless, almost insoluble in water, but soluble in solution of iodide of potassium. 0.003 G. ($\frac{1}{20}$ gr.); B. P., $\frac{1}{32}$–$\frac{1}{16}$ gr.

This preparation is very seldom prescribed as such, but is frequently formed by prescribing a mixture of corrosive sublimate and potassic iodide, when the iodide of mercury is formed and is kept in solution by the excess of the iodide of potassium. This prescription is often indicated in tertiary syphilis. The yellow or green iodide of mercury (HgI) has also been used in syphilis, but has no advantages over calomel.

Liquor Arseni et Hydrargyri Iodidi (U. S. P., B. P.), Donovan's solution, contains 1 per cent. each of arsenic iodide and red mercuric iodide. 0.1 mil ($1\frac{1}{2}$ mins.); B. P., 5–20 mins.

Unguentum Hydrargyri Iodidi Rubri (B. P.), 4 per cent.

Calomel (page 103) is used in syphilis (dose, 0.05 G. (1 gr.) thrice daily), but is credited with being more liable to induce salivation than other preparations, and its purgative action often has to be counteracted by opium. A suspension of 1 part calomel in 20 parts of 10 per cent. salt solution or liquid paraffin is often injected into the buttock in syphilis; the dose of calomel by this method is 0.05–0.1 G. (1–$1\frac{1}{2}$ grs.) once a week. It is of great value in some forms of dropsy, especially those of cardiac origin, in which it is administered in 0.2 G. (3 gr.) doses thrice a day for two to four days, and is stopped as soon as the diuresis sets in. The treatment may be repeated if the dropsy returns.

Calomel has been used externally as a dusting powder for syphilitic chancres and condylomata, as a slight irritant to the cornea, and as an ointment in pruritus and other skin diseases.

Blue Pill and Gray Powder (page 103).—Blue pill is often given in cardiac dropsy along with squills or digitalis, but has proved inferior to calomel as a diuretic. Gray powder is held by some authorities to be the best form for the internal treatment of syphilis, and is given in doses of 0.05 G. (1 gr.) 3 to 5 times a day; if necessary, opium may be given to prevent purging. The blue pill may also be used in syphilis and is less liable to purge.

Unguentum Hydrargyri (U. S. P., B. P.), mercurial ointment, blue ointment, is formed by triturating metallic mercury with lard and suet until the globules are invisible when magnified ten diameters. The ointment contains about 50 per cent. of metallic mercury U. S P., 30 per cent. B P.

Unguentum Hydrargyri Compositum (B. P.) contains 12 per cent. of mercury along with camphor.

Unguentum Hydrargyri Dilutum (U. S. P.) contains 33 per cent. of mercury.

The famous blue ointment is used largely in many forms of skin disease, especially in those of syphilitic origin, and was formerly the ordinary treatment for scabies, in which, however, it has been supplanted by balsam of Peru and other remedies, though it is still used occasionally to destroy pediculi. The most important purpose for which blue ointment is applied at the present time is the treatment of syphilis by inunction. For this purpose 2–4 G. ($\frac{1}{2}$–1 dr.) is rubbed in daily in different parts of the body, in order to avoid the irritation induced by applying it repeatedly to one spot. A warm bath is taken first, and the patient then rubs in the ointment on the inside of the thighs, next day on the inside of the arms, on the following days on the forearms, legs, abdomen and back, returning to the thighs on the seventh day and repeating the series. The treatment is continued for a fortnight or three weeks. This method has the advantage that the digestion is less affected than when the drug is given internally, but on the other hand, the mercury is more slowly absorbed than by other methods; and no estimate of the quantity really taken up can be formed, as, although the patient is directed to rub it in until the whole disappears, the instructions may be imperfectly carried out. Salivation is not so readily produced as by the administration per os, but when it occurs, it lasts longer and may become severe. One case of fatal poisoning has been recorded from the application of the ointment, but in this case the skin appears to have been broken. Skin rashes are more frequent from inunction than from any other method of application, and finally, the method is extremely inconvenient and dirty. In children the ointment is often applied by spreading it on a bandage which is then applied around the waist. In skin disease and in very hirsute individuals, the inunction treatment is impossible.

Oleum Cinereum, or gray oil (not official), is a suspension of metallic mercury in liquid paraffin or in wool-fat and oil, and is used in syphilis by intramuscular injection. It often is made up to contain 20 per cent. of mercury, and the dose is then 2–3 c.c. once a week. Lambkin's Cream is a similar 10 per cent. suspension of mercury in wool-fat and liquid paraffin.

Oleatum Hydrargyri (U. S. P.), *Hydrargyrum Oleatum* (B. P.), oleate of mercury, has been used for the same purposes as mercury ointment, but is somewhat more irritant and possesses no compensating virtues.

Unguentum Hydrargyri Oleati (B. P.), 1 part in 4.

Emplastrum Hydrargyri (B. P.), mercury plaster, is formed in the same way as the ointment by the trituration of metallic mercury.

The plaster is sometimes applied to chancres and to syphilitic ulcers, and has been used instead of the ointment as a treatment of syphilis.

Hydrargyri Oxidum Flavum (U. S. P., B. P.), yellow mercuric oxide.

Hydrargyri Oxidum Rubrum (U. S. P., B. P.), red mercuric oxide.

Unguentum Hydrargyri Oxidi Flavi (U. S. P., 10 per cent., B. P., 2 per cent.).

Unguentum Hydrargyri Oxidi Rubri (B. P.), 10 per cent.

The two oxides are identical in constitution (HgO), but the yellow is obtained by precipitation from the perchloride, the red by oxidation of the metal by means of nitric acid. The red is crystalline, the yellow amorphous, and both are practically insoluble in water and alcohol, but are soluble in acids. The red oxide is more irritant than the yellow on account of its crystalline form, and perhaps also because it often contains some nitrate. The yellow oxide is used in ointment in various diseases of the eye, and both are employed as applications to syphilitic sores, condylomata and chancres, although the red is often preferred for this purpose.

Two famous preparations of mercury are the black and the yellow wash, the former prepared from calomel, the latter from corrosive sublimate by the action of lime water. The black wash, *Lotio Hydrargyri Nigra* (B. P.), contains mercurous oxide (Hg_2O), the yellow, *Lotio Hydrargyri Flava* (B. P.), mercuric oxide (HgO). The oxides are in both cases insoluble and the lotions have to be shaken before application. They are used in syphilitic lesions as local remedies.

Hydrargyrum Ammoniatum (U. S. P., B. P.), mercuric ammonium chloride, white precipitate (NH_2HgCl), is formed by precipitating corrosive sublimate with ammonia, and is a white, amorphous powder, without odor and with an earthy, metallic taste, almost insoluble in water and alcohol.

Unguentum Hydrargyri Ammoniati (U. S. P.), 10 per cent., (B. P.), 5 per cent.

The white precipitate is not used internally and is more irritant than the oxides. The ointment is occasionally applied in skin diseases and to destroy parasites.

Unguentum Hydrargyri Nitratis (U. S. P., B. P.), citrine ointment, is used, diluted with oil or lard, in conjunctivitis, and also as an application to syphilitic sores and gangrenous ulcers; it is acid and strongly irritant.

Unguentum Hydrargyri Nitratis Dilutum (B. P.), citrine ointment diluted to one part in five.

A large number of new preparations of mercury have been introduced of late years and have received a more or less extensive trial, but have seldom been found to be superior to the older forms. Among these may be mentioned the *tannate*, which was introduced in the hope that it would cause less purgation than calomel, and might therefore be better adapted for the treatment of syphilis. 0.1–0.3 G. (2–5 grs.) in powder. The *carbolate*, *salicylate* (*either neutral or basic*), *benzoate*, *sozoiodolate*, *thymol-acetate* and many other similar compounds have been used instead of calomel for hypodermic or intramuscular injection, have each in succession been blazoned forth as the best preparation, and will probably be forgotten in the course of a few years. The salicylate (*Hydrargyri Salicylas*, U. S. P., 0.004 G. ($\frac{1}{15}$ gr.) is said to be excreted more rapidly than the inorganic salts. Several amino-acid salts of mercury such as the *formamide*, the *amino-propionate* (alanin mercury) and the *succinimide* have been proposed as substitutes for corrosive sublimate in hypodermic injection. It was believed that the affinity of mercury for nitrogen being satisfied in these compounds, it would attack the proteins less, and as a matter of fact, the injections are said to be less painful that those of corrosive sublimate. *Colloid mercury* (*Hyrgol*) has been injected intramuscularly, but has no advantage over the older preparations. Several organic mercury combinations in which the metal is attached directly to the carbon have been formed, but have not yet proved superior to the older forms in practice.

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III. IRON.

Iron differs from the other heavy metals in being essential to the life of many, perhaps all, forms of protoplasm. In the vertebrates this is obscured by the fact that most of the iron is contained in the hæmoglobin of the blood, and its importance in the other tissues is generally ignored. In the invertebrates, however, in many of which no corresponding compound exists in the blood, considerable amounts of iron are found in the tissues, and there is no question that throughout the animal kingdom iron is essential to living matter, quite apart from its special relation to the blood in the vertebrates. Molisch has shown that it is also necessary for the development of the lower vegetable forms, and it has been found that in its absence the higher plants fail to form chlorophyll, although iron is not actually contained in the latter as it is in hæmoglobin.

The iron combinations vary in the readiness with which they liberate the iron ion and therefore in the facility with which they react with such reagents as ammonium sulphide or potassium ferrocyanide; the more dissociable salts, such as the chloride or acetate, are sometimes known as "inorganic iron" while compounds such as hæmoglobin, which do not dissociate the iron ion, are termed masked or "organic" iron; between these two extremes there lie many intermediate forms, which react slowly to the sulphides and other tests.

The dissociable iron salts precipitate proteins from solution and thus act as astringents or irritants (page 611) according to the concentration in which they are applied; but iron has no specific poisonous action on living matter such as is possessed by mercury or antimony, and the

irritation induced by such salts as the perchloride arises from the acid constituent and not from the metal. The less dissociable compounds, such as the double salts and "organic" iron, do not precipitate proteins, and are therefore neither irritant nor astringent as long as they maintain their original form and are not decomposed into simple salts.

Symptoms.—Inorganic iron compounds, of which the perchloride may be taken as a type, have an astringent, metallic, or often acid taste, but in ordinary doses induce no further symptoms. If swallowed in large quantities, they cause pain and uneasiness in the stomach, nausea, vomiting and often purging, with all the ordinary symptoms of acute gastro-intestinal irritation. General weakness and even collapse may be induced, but are manifestly secondary to the gastric and intestinal effects, and no symptoms which can in any way be attributed to the absorption of iron have been observed in either man or animals.

The prolonged use of inorganic iron is frequently followed by some dyspepsia and by constipation and colic, which are obviously due to the continued astringent action on the stomach and bowel. Other symptoms observed occasionally are blackness of the teeth and tenderness in the gums, which may be due to the acid contained in many iron preparations; the blackening of the teeth has been supposed to be due to the tannic acid of the food precipitating the inky black tannate of iron, or to the sulphide of iron being formed by the action of the hydrogen sulphide present in carious teeth. According to Buzdygan, the iron preparations increase the secretion of hydrochloric acid in the stomach, and may thus lead to hyperacidity, or aggravate it if already present. In artificial digestion, the salts of iron with organic acids are said to hinder the process more than those with inorganic acids, the ferric salts more than the ferrous, and the insoluble preparations least of all. The digestion of starch is almost unaffected by the presence of iron.

Iron given by the mouth induces leucocytosis (Pohl), and does not affect the amount of double sulphates excreted in the urine, so that it has no antiseptic action in the bowel (Mörner).

Some symptoms from the circulation are sometimes said to arise, but are for the most part subjective, and seem to be handed down by tradition rather than really observed. These are a feeling of congestion, fulness and heat in the head and hæmorrhages from the nose, throat and lungs, especially in phthisis. If these symptoms are not entirely imaginary, they are to be attributed to some reflex from the stomach and intestine and not to any direct action of iron on the heart or vessels.

When these astringent preparations are injected into the bloodvessels in animals, they coagulate the proteins and cause thrombosis but no real symptoms of iron poisoning. Fatal thrombosis has been observed in patients from the injection of the perchloride into the uterus and also into nævi. The hypodermic injection of these salts causes some pain and swelling, but no further symptoms follow, and the iron is found for the most part deposited in an insoluble form at the point of injection.

The **General Action** of iron is obtained only by the intravenous injection of double salts, such as the tartrate of iron and sodium, which do not coagulate

the blood and at the same time are capable of freeing the iron ion in the tissues. Such salts as the ferrocyanides or ferricyanides on the other hand leave the body unchanged, and the iron ion is not liberated, so that no iron symptoms are induced. Meyer and Williams found that the double tartrate caused in the frog slowness and clumsiness in movement, which gradually developed into complete paralysis of the central nervous system. The heart seemed to be little affected, but the skeletal muscles were somewhat less irritable than usual after death. In mammals the symptoms of iron poisoning were often very late in appearing, and began with some acceleration of the breathing, which later became slow and dyspnœic; vomiting and diarrhœa often followed and blood was sometimes seen in the evacuations of the stomach and bowel. Increasing weakness was followed by central paralysis and death, accompanied by weak convulsive movements. The heart seemed little affected, although the blood-pressure fell rapidly toward the end. Postmortem, the mucous membranes of the stomach and intestine were found swollen and congested, and often contained numerous small blood extravasations. Kobert found that repeated injection of small quantities of the citrate of iron induces congestion of the kidney and the appearance of casts and albumin in the urine.

Iron, like the other heavy metals, would therefore seem to have a specific irritant effect on the intestinal and gastric mucous membrane, and to a less extent on the kidney. In addition, it depresses and eventually paralyzes the central nervous system, but it is impossible to state how far this is due to direct action and how far it is secondary to the action in the alimentary canal.

Absorption and Distribution.—Iron has long been used in the treatment of anæmia, more especially of the form known as chlorosis, in which it has often the happiest results.

The absorption of the iron preparations, at one time the subject of acute controversy, has been shown both by the chemical analysis of the organs and by histological methods. The chief difficulties to be overcome arose from iron being a normal constituent of all the tissues and from the very small quantities that suffice to maintain health. About $2\frac{1}{2}$–$3\frac{1}{2}$ G. (40–55 grs.) of iron are estimated to be present in the tissues of a healthy human adult, the greater part of it existing in the form of hæmoglobin in the blood. Stockman and Greig showed that an ordinary dietary provides only about 5–10 mgs. ($\frac{1}{12}$–$\frac{1}{6}$ gr.) of iron per day; they found in one case that even 3–5 mgs. ($\frac{1}{20}$–$\frac{1}{12}$ gr.) were sufficient to preserve the iron equilibrium. About the same amount of iron is excreted per day, chiefly in the fæces, and to a smaller extent in the urine.

When additional iron is supplied, the quantity in the stools is greatly increased, while no change is seen in the iron of the urine; even when a double salt is injected intravenously, only a trace is found in the urine, and when it reaches the blood more slowly the proportion eliminated in this way falls. The fact that an iron preparation given by the mouth does not increase the iron in the urine is therefore no evidence that it has not been absorbed.

Iron injected into the veins of animals is stored up in the liver, spleen and bone-marrow, but is taken up from these organs again, and is excreted by the epithelium of the cæcum and colon. When iron is given by the mouth, therefore, it may either pass along the canal and be thrown out in the fæces, or it may be absorbed, make a stay in the liver, be excreted in the large intestine, and again appear in the

stools. The comparison of the iron in the food and in drugs with that of the stools therefore gives no clue as to how much has been absorbed and how much has simply passed through the intestine.

But the passage of iron from the liver to the intestine is a somewhat slow process, and it is therefore possible to detect the excess of iron in the liver. This has been done repeatedly by the following method. Young animals of the same litter, fed on milk, have approximately the same amount of iron in the liver. If one be fed on milk only, another on milk to which iron is added, the liver of the latter is found to contain more iron than that of the control. Other investigators have fed animals (rats or mice) on food that is practically free from iron, have killed them and estimated the iron in the whole body apart from the alimentary tract, and compared it with that of animals treated in the same way except that iron was added to the food. The latter group contains more iron than the control group fed on iron-free food, and in general presents a more healthy and normal appearance.

Finally, iron has been followed in its course through the tissues by histological methods, reagents being used which color most forms of iron, but leave the hæmoglobin unaffected. When animals are given iron preparations, and are then killed and their organs stained by these reagents, the mucous membrane of the stomach and of the greater part of the small intestine gives no coloration, but the epithelium of the duodenum and the upper part of the jejunum is found to contain numerous granules of iron. These granules may be traced to the mesenteric lymph glands, are found in large numbers in the spleen around the corpuscles, to a smaller extent in the liver, and in the cortex of the kidney. If, however, the animal be kept for some days after the iron is given, the reaction in the duodenum, spleen and mesenteric glands is less intense, while the liver gives more distinct evidence of containing iron, and the epithelial cells of the large intestine and cæcum also give a strong reaction. This means that iron is absorbed by the duodenum and is first stored in the spleen, but later finds its way through the bloodvessels to the liver, where it rests again for some time, to be eventually taken up again by the blood and excreted into the large intestine and the cæcum. It seems to travel by the bloodvessels and not in the lymph, and the administration of iron does not increase the amount of iron in the bile.

Nothing is known regarding the changes which the preparations undergo in the stomach and intestine or the form in which iron is absorbed; it may be taken up in solution, or may be precipitated and taken up as solids by the epithelial cells and the leucocytes. In the liver it seems likely that the absorbed iron is changed to indissociable compounds (ferratin), several of which have been found.

It must not be inferred from the foregoing that all of the inorganic iron swallowed is taken up by the intestinal epithelium. It is quite impossible to form even approximate estimates of the amount that is really absorbed and made use of by the tissues, but the probability is that only a small percentage is really taken up; the rest passes

through the intestine and is thrown out in the stools. It is often stated that the iron stools are dark or black in color, from the sulphide present, but this seems to be seldom the case when they are passed, although they assume a darker gray or grayish-black color in the air, from oxidation. The iron is contained in them only to a small extent as the sulphide.

To sum up what is known regarding the fate of the iron preparations, they probably undergo some changes in the stomach and then pass into the duodenum, from which the great bulk is carried on into the lower parts of the intestine, while some is absorbed by the epithelium and leucocytes in solid form and perhaps in solution. It is then deposited in the spleen, where it may undergo some changes in form, is later taken up by the blood and deposited in the liver and perhaps in the bone marrow. Where the supply of iron has been inadequate for the formation of hæmoglobin, the originally inorganic iron is probably worked into higher forms and eventually into hæmoglobin in the liver, and it seems likely that ferratin is one of the intermediate steps in this synthesis. When there is no deficiency of iron for the formation of hæmoglobin, the liver slowly yields its store of iron to the blood, which carries it to the cæcum and large intestine, by the epithelium of which it is finally excreted. It is to be noted that the iron absorbed does not increase the amount of iron in the urine, bile, or other excretions. The ordinary preparations of iron follow the same course in the tissues as the more complex compounds which exist in foods.

But this explanation of the iron action does not cover all the difficulties of the case. Many cases of chlorosis recover without inorganic iron under hygienic conditions, such as rest, and particularly when foods rich in iron are prescribed, this being exactly what is to be expected on the theory that inorganic iron merely takes the place of the deficient food-iron. But many chlorotic patients show little or no improvement when treated with foods containing iron, even when there is no question that the iron supplied daily in food form is sufficient for the needs of the economy, and chlorosis even appears in individuals who have never suffered from any deficiency of food-iron. Yet many of these cases recover rapidly under inorganic iron, and this has led to the suggestion that inorganic iron when absorbed acts as a stimulant to the blood-forming organs, while food iron has no such property. This view has been ably criticized by Zahn, who shows it to be untenable. He found that in animals rendered anæmic by hæmorrhage and then treated with foods rich in iron, the recovery is not accelerated by iron salts as would be expected if the blood formation were actually stimulated by iron; he therefore believes that the curative action of the iron preparations in anæmia may be explained by the abundance of the material offered to the blood-forming organs rather than by their being stimulated in the ordinary sense. The difference in the effects of the irons of the food and of the inorganic preparations may be due to the fact that food-iron is always accompanied by a large amount of colloid material, which may materially delay its absorption, while

inorganic iron on the other hand is much less completely enveloped, and may be more easily absorbed. In addition, the iron preparations are given in much larger amounts than the food-irons. When 10 mgs. of food-iron are taken per day, only a small proportion (*e. g.*, 5 mgs.) may be absorbed, and this may be insufficient to supply the needs of the body, but if some hundreds of milligrams of inorganic iron be added, the proportion absorbed will be amply sufficient. The same effect might be obtained by the same amount of food-iron, but this is only to be obtained by giving more food than can be digested.

Iron is not absorbed from the unbroken skin, and the iron and steel baths are therefore of no value in themselves in the treatment of anæmia.

No account of the action of iron would be complete, without reference to Bunge's view which formerly attracted a large amount of attention, though it has now been abandoned. His theory was that in ordinary conditions a certain amount of iron is lost by the body constantly through the excretions, and this loss is made up by the absorption of the iron contained in the food. This food-iron consists wholly of organic iron, that is, of iron combined in such a way that sulphides attack it with difficulty; an example of such organic iron is the hæmatogen of the yolk of egg. In normal individuals the food-iron is sufficient to replace that lost by excretion, but in chlorosis the presence of large amounts of sulphides in the intestine causes the food-irons to be decomposed to ferric sulphide, which is insoluble and unabsorbable. When the ordinary inorganic iron preparations are administered in these cases, they are not taken up in place of the food-iron; but, by forming sulphide in the intestine, they remove the sulphuretted hydrogen and prevent the decomposition of the food-irons, which thus remain capable of being absorbed. Bunge and his followers went on to state that inorganic iron is never under any circumstances absorbed by the normal epithelium, but that when large quantities are administered, they tend to corrode the walls of the stomach and intestine, and are thus absorbed to some extent. Even then, however, they are incapable of being formed to hæmoglobin, the animal body being able to perform only the last steps of this synthesis after the plants have formed the simpler types of organic iron. This theory now possesses only historical interest, so that it is unnecessary to enumerate the arguments brought against it. It may be sufficient to state that if the ordinary preparations of iron acted only by binding the sulphides of the intestine, various other metals would be equally efficient in chlorosis; iron would not be beneficial injected hypodermically, and iron sulphide given so as to escape the action of the gastric juice would be equally useless. It is found, however, that no other metal can replace iron in chlorosis; that iron injected hypodermically is curative in chlorosis, and that the sulphide administered so as to reach the intestine unchanged acts as well as other preparations (Stockman). Finally, it has been shown that ordinary preparations of iron are absorbed.

Therapeutic Uses.—Iron is most frequently used in the treatment of **Chlorosis**, in which its reputation is attested by the old saying "Qui nescit Martem,[1] nescit artem." A large proportion of cases recover entirely under it. Some however, improve under iron, but relapse when it is left off, and a certain number of patients show no improvement whatever under it. These last are not generally regarded as suffering from chlorosis proper, but from a more malignant form of anæmia. The effects of iron are seen in an increase in the hæmoglobin of the blood, while the number of corpuscles may show little alteration,

[1] In astrological medicine iron was associated with the planet Mars.

though a considerable rise occurs in some cases. A number of symptoms which are due to chlorosis, and which are often more prominent than the original disease, are also relieved or entirely removed by iron. Thus gastric catarrh, amenorrhœa, or œdema may disappear under it, but in these cases the symptoms are chlorotic in origin, and the improvement is due to the increased hæmoglobin, and not to the direct action of iron on the stomach, uterus, or circulation.

In chlorosis the iron is generally given in small doses, at any rate at first, and the less astringent preparations are preferred by most clinicians, although some still advise the perchloride. When chlorosis is complicated with gastric catarrh, some authorities advise that the latter be treated before the general condition, as iron in itself is liable to irritate the stomach. In many cases, however, the catarrh is secondary to the chlorosis, and can only be treated successfully by improving the condition of the blood; the iron preparation here ought to be mild and not irritating. In chlorosis the tendency to constipation may be increased by iron, and a purge is often required, such as the iron and aloes pill, which is particularly recommended when chlorosis is attended by amenorrhœa.

Iron is of less value in other forms of anæmia, although it is often prescribed and may be followed by some improvement. Thus it may be administered during convalescence from acute disease, such as typhoid fever or nephritis; there is some doubt of its value in the anæmia induced by profuse hæmorrhage though it is often prescribed for it. It is often prescribed for the cachexia of malaria, syphilis, and other chronic diseases.

Arsenic is also used in many forms of anæmia, but appears to differ from iron in accelerating the growth and renewal of the corpuscles rather than increasing their content of hæmoglobin. Both arsenic and iron may be advisable in some anæmias. Iron was formerly considered to be contraindicated in fever, plethora, heart disease and pulmonary phthisis from an apprehension that it tended to cause hæmorrhage. But there seems no basis for this view. In phthisis it should be given with caution in order to avoid irritation of the stomach and dyspepsia, and in the presence of gastric catarrh from any cause, its effects have to be watched carefully.

Some of the older authorities advise iron to be given in large quantities, but the dose has been reduced of late years to about 0.1–0.2 G. (2–3 grs.) three times a day. It is given after meals in order to avoid the irritant action on the stomach as far as possible. It is to be noted that on giving 0.1 G. of iron three times a day, about thirty times as much iron is given as is required normally in food, so that the chlorotic receives more iron per day than a workman in a month.

Iron is occasionally injected hypodermically, with the object of avoiding the irritation of the stomach, but this procedure is painful and causes some swelling and irritation, which lasts twenty-four hours or more. Most of the salts are precipitated at the point of injection, but some, such as the citrate, are taken up by the blood at once; the

danger of renal irritation, anticipated by Kobert, does not seem to arise if small quantities are used; 1–2 grs. are injected in 5 per cent. solution daily.

Iron is seldom used as an **Astringent** now, although the sulphate had some reputation for this purpose formerly.

Similarly, its use as a **Styptic** is rapidly becoming less, as it is less reliable than the local vasoconstriction induced by adrenaline. The perchloride was formerly employed for this purpose and acted by precipitating the proteins of the blood and thus forming an obstruction to the flow of blood from the wounded vessel. The treatment is of value only for oozing from capillaries or small arterioles and the iron must be brought into immediate contact with the bleeding point. Its use in hæmorrhage from the stomach and bowel is unlikely to be successful from the difficulty in concentrating its action on the point from which the blood is escaping. It has been injected into the uterus in hæmorrhage, into nævus in order to cause coagulation and subsequent cicatrization of the tissue, and into aneurisms. This is a very dangerous treatment, however, for several cases of fatal embolism have arisen from the precipitated protein being carried off in the veins. Perchloride of iron solution has been sprayed into the air passages in hæmoptysis, but if sufficiently concentrated to coagulate the blood at the bleeding point in the lungs, it would certainly induce irritation and coughing. The perchloride is, of course, valueless in hæmorrhage from internal organs, for in the first place, very little of it is absorbed, and in the second place, what does pass into the tissues is already in protein combination, and therefore incapable of coagulating the blood. The same objection applies to the alleged astringent effect of iron in nephritis.

The sulphate of iron is used as a disinfectant for sewage. It acts here merely by precipitating the proteins, which carry down the bacteria mechanically. The proteins of the sewage may be increased by the addition of blood before the sulphate is applied. The sulphate of iron is used, because it is cheaper than the other salts of the heavy metals.

Preparations.

Ferri Sulphas (U. S. P., B. P.), ferrous sulphate ($FeSO_4+7H_2O$), large, pale, bluish-green crystals with a saline, astringent taste, soluble in water, insoluble in alcohol, and unstable in moist air. 0.1 G. ($1\frac{1}{2}$ grs.), B. P. 1–5 grs.

The sulphate of iron is very astringent, though less so than the ferric salts. It is used as an astringent application to mucous membranes, such as the eye, mouth, urethra, more rarely internally in anæmia.[1]

The *Pil. Aloes et Ferri* (B. P.), which is used very largely in amenorrhœa and in chlorosis with constipation, contains dried sulphate of iron. Dose, 4–8 grs.

Ferrum Reductum (U. S. P.), Ferrum Redactum (B. P.), reduced iron, a very fine, grayish-black, lustreless powder, without taste, insoluble in water or alcohol, soluble in acid. It consists of metallic iron, with a small amount of the magnetic oxide. 0.06 G. (1 gr.); B. P., 1–5 grs.

Ferri Carbonas Saccharatus (U. S. P., B. P.), saccharated ferrous carbonate, is formed by precipitating ferrous sulphate with sodium bicarbonate, washing the precipitate and adding sugar. It contains ferrous carbonate along with some ferrous sulphate and sodium bicarbonate, and is a greenish-brown powder, which rapidly oxidizes in the air, and has a sweetish, astringent taste. The carbonate is a very unstable body and on keeping is slowly transformed to ferric hydrate ($Fe_2(OH)_6$). The sugar is added in order to retard this oxidation, but the carbonate ought not to be dispensed unless it is of recent preparation. 0.25 G. (4 grs.); B. P., 10–30 grs.

[1] The dried sulphate is used to form Blaud's pill. Another sulphate preparation is the *Liquor Ferri Subsulphatis* (U. S. P.), or Monsel's solution, which is superfluous.

Pilulæ Ferri Carbonatis (U. S. P.), Pilula Ferri (B. P.) ferruginous or chalybeate pills, blaud's pills, are prepared in the same way, by the action of ferrous sulphate and carbonate of potash or soda. Sugar, tragacanth, and glycerin are added; they ought to be freshly prepared in order to avoid the formation of the hydrate. Dose, 2 pills U. S. P., 5–15 grs. B. P.

Mistura Ferri Composita (B. P.), Griffith's mixture is formed by mixing ferrous sulphate, potassium carbonate, and various flavoring substances. The ferrous carbonate($FeCO_3$) is precipitated, and the mixture has therefore to be shaken before taking, and ought to be freshly prepared. 16 c.c. (4 fl. drs.); B. P., ½–1 fl. oz.

Reduced iron and the four carbonate preparations are used exclusively in the treatment of anæmia. They are practically devoid of irritant properties, and are among the best of all the iron preparations for this purpose. The Blaud's Pills have in particular a well merited reputation in the treatment of chlorosis and of chlorotic amenorrhœa. Another preparation used for this purpose but not official is *Ferrum Dialysatum*, in which a considerable amount of iron oxide is kept in a colloid state along with a minimum amount of the chloride. It tastes of iron but is not astringent.

Ferri et Quininæ Citras (U. S. P., B. P.), thin scales of a golden-yellow color, and of a bitter, iron taste, soluble in water, partially soluble in alcohol, containing 11.5 per cent. of quinine and 13 per cent. of iron U. S. P. 0.25 G. (4 grs.); B. P., 5–10 grs.

Ferri et Ammonii Citras (U. S. P., B. P.), thin garnet-red scales with a salt, iron taste, soluble in water and containing 16 per cent. of iron. 0.25 G. (4 grs.); B. P., 3–10 grs.

These two double salts of iron (scale preparations) have been used in chlorosis and especially in convalescence from acute fevers, which is often accompanied by anæmia. The iron is not readily dissociated and these preparations are therefore not astringent and do not disturb the digestion. But they are not superior to Blaud's pills in this respect.

Pilulæ Ferri Iodidi (U. S. P.), each contains 0.04 G. of iron. 2 pills.

Sprupus Ferri Iodidi (U. S. P., B. P.) contains about 5 per cent. of the iodide (7 per cent. B. P.). Dose 1 mil (15 mins.); B. P., ½-1 fl. dr.

These preporations have been prescribed to a greater or less extent in the treatment of anæmia. The iodide has been advised in order to combine the effects of iodide and iron, but the iodide given in this form is in much smaller quantity than that found necessary in the iodide of potassium treatment, and it seems open to question whether the improvement is not due to the iron only.

Syrupus Ferri Phosphatis cum Quinina et Strychnina (B. P.). 4 mils (½–1 fl. dr.).

This syrup is used as a "general tonic" and probably owes what value it possesses to the iron it contains.

Liquor Ferri Chloridi (U. S. P.), a strongly acid solution of ferric chloride containing 10 per cent. of iron. 0.1 mil (1½ mins.).

Tinctura Ferri Chloridi (U. S. P.) contains 4.5 per cent. of iron. 0.5 c.c. (8 mins.).

Liquor Ferri Perchloridi Fortis (B. P.) is formed by dissolving iron in hydrochloric acid, and contains 20 per cent. of iron. It is an orange-brown fluid, with a strong acid astringent taste.

Liquor Ferri Perchloridi (B. P.) and

Tinctura Ferri Perchloridi (B. P.) contain about 5 per cent. of iron. Dose 5–15 mins.

The chloride is used as a styptic either as the Liquor Fortis (B. P.) or in a very much stronger form, prepared by allowing the crystals to deliquesce. A plug of cotton-wool steeped in the solution is used to stop bleeding after the extraction of teeth. When diluted it may be used as a gargle, but has a disagreeable, inky taste, and attacks the teeth. The tincture is used in the treatment of chlorosis under the name of "steel drops," but is irritant and therefore inferior to the milder preparations.

Iron is contained in many *mineral waters*, which are therefore advised in cases of anæmia. It is generally in the form of the carbonate, which is dissolved by the excess of carbonic acid present, but becomes oxidized to the insoluble ferric hydrate in the air. The amount of iron contained is small, seldom being more than 0.1 G. per litre, but the treatment of chlorosis is unquestionably aided by change of scene and in particular by the high elevations at which many of these springs are situated, so that the success of treatment with these iron waters is perfectly intelligible. Bathing in iron water has no further action on the blood than ordinary baths, as no iron is absorbed.

Many **Protein Compounds** of iron, such as the *albuminate, peptonate* and artificial *ferratin*, have been introduced into therapeutics, but possess no advantage over the usual preparations, which they resemble in their reactions to sulphide and other tests.[1]

Blood has been used in therapeutics by uncivilized peoples since time unknown, and has also been recommended in modern medicine in the treatment of chlorosis, in which it is administered by the mouth, and also hypodermically, though the latter method is difficult to carry out aseptically. *Hæmoglobin* has also been advertised largely of late years in a more or less impure form. In the stomach, hæmoglobin, whether contained in blood or as crystals, is changed to hæmatin; Abderhalden found that both hæmoglobin and hæmatin are absorbed and lead to an increase in the hæmoglobin of the blood, but these forms are in no way superior to the older ones and are therefore superfluous.

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[1] To these and similar preparations the lines of Garth (1706) may be applied.

Till the Green sickness and Love's force betrayed
To Death's remorseless arms the unhappy maid.
. . . Oh that instead of trash, she'd taken steel!

IV. LEAD.

Lead is used to some extent in therapeutics, but its chief interest from a medical point of view lies in the frequency with which it gives rise to chronic poisoning, and in the diversity of the symptoms presented in that condition.

Solutions of lead salts precipitate proteins, and this precipitate is formed when lead solutions are applied to the mucous membranes and protects them. The metal contained in the precipitate is not destructive to the cells as in the case of mercury, so that the lead salts are less corrosive; and the salts chiefly used are the acetates, whose acid is only slightly active, so that the astringent action of the protein precipitate is the chief feature of the action. Solutions of lead nitrate are irritating and corrosive, however, because it is more readily dissociated and the nitric acid freed is itself corrosive.

Symptoms. — In ordinary therapeutic doses, the acetate of lead (sugar of lead) has a sweetish, metallic taste followed by a feeling of astringency, and induces no symptoms except constipation. The stools after lead are often said to be dark in color from the sulphide formed in the intestine, but this does not seem to be the general rule. Probably little lead is absorbed from an ordinary dose of the acetate; at any rate no symptoms arise from the general action of the metal absorbed.

Lead acetate solutions applied to the skin have no effect, but mucous membranes, or exposed tissues, such as ulcers, are covered with a thin pellicle of precipitate, which serves to protect them from irritation, and thus promotes their healing.

When very large quantities of acetate are swallowed, particularly if in a concentrated form, they give rise to the ordinary symptoms of irritant poisoning, nausea, vomiting, pain in the abdomen, violent purging or sometimes constipation, blood in the vomited matter and stools, great thirst, weakness, and collapse. In some instances in which the patients recovered from these symptoms, they subsequently suffered from chronic lead poisoning, but apart from these, nothing in the course of acute lead poisoning suggests the absorption of the metal, all the symptoms being obviously due to the local effects on the stomach and bowel, and to the consequent collapse. In fact the effects of a sudden absorption of lead are unknown in man or animals.

Continued ingestion of small quantities by way of the stomach, or by inhalation by the lungs, induces chronic poisoning, which can be explained only by its absorption. There seems some reason to believe that lead is absorbed from the unbroken skin, though it is possible that some of the metal was carried to the mouth and swallowed with the food in the cases on which the statement is founded. Lead is apparently **Absorbed** more rapidly than most of the metals except mercury, and remains lodged in the tissues a long time, the excretion taking place only very slowly. It is found in most organs in cases of poisoning, particularly in the liver and kidney. It is **Excreted** in the

urine, the bile, the secretion of the intestinal epithelium, in the milk and saliva, and in traces in the perspiration.

Chronic Lead Poisoning is the commonest of all forms of metallic poisoning, and at the same time one of the most insidious. It is always accidental, and although it is most common in workers in lead, may occur in persons who are not apparently liable to come in contact with the metal. There is no question that some people are more susceptible to lead than others and that sometimes persons who have suffered from the early symptoms recover and prove resistant to the further action of the metal. Anæmia and weakness from any cause are generally believed to predispose to the disease, women and children are more liable to it than men, and alcoholism and previous lead intoxication increase the tendency to the attack. Relapses are very common, and may occur years after the first symptoms, even although there has been no further exposure in the interval. Lead smelters, workers in white lead factories, painters, plumbers, electricians, and typesetters are liable to lead poisoning from continually handling the metal; but other trades are not exempt from it, and sometimes the channels by which it gains entrance to the body are very obscure. Trades which have recently yielded a considerable number of cases are pottery, from the use of a lead glaze, and coach-painting from the rubbing down of the layers of paint. Some of the more common causes of poisoning are lead water-pipes or cooking utensils, lead used to close tins of meat or fruit, and lead in hair dyes. Formerly a common source of poisoning was wine and cider to which lead had been added to reduce the acidity. A considerable number of cases of poisoning have been recorded from the use of lead preparations as abortifacients. Chronic lead poisoning has been induced experimentally in animals by the inhalation of lead carbonate dust and in birds by passing lead shot into the crop.

The symptoms of chronic lead poisoning vary greatly in different cases, sometimes only one or two organs being attacked, in others the whole economy appearing involved in the disorder. The symptoms may be divided into groups for convenience, but it is to be noted that many of these appear to be closely inter-connected, and that in many cases it is impossible to decide whether a set of symptoms is due to direct action upon a single organ, or to the simultaneous disease of several.

The **Mouth, Stomach and Digestion** very often give early indications of lead poisoning. The patient complains of loss of appetite, nausea, constipation, wasting, a metallic taste and fœtid breath, and a blue-black line is seen along the margin of the teeth where they enter the gums. This "lead line" is due to the precipitation of lead sulphide by the hydrogen sulphide arising from septic processes in the teeth and gums; it is often absent if the teeth and mouth are kept clean and healthy, and its presence does not indicate lead poisoning, but only contact with lead. The metallic taste seems due to the excretion of lead in the saliva, and the loss of appetite may arise from the same cause. These symptoms may be produced in animals also.

Another early symptom is **Anæmia,** which may be due in part to malnutrition, but is attributed mainly to an abnormal destruction of the red cells of the blood; the white corpuscles are increased in many cases but not in all. It is often accompanied by jaundice, with the highly pigmented urine and other symptoms which usually follow the liberation of large quantities of hæmoglobin from the breaking up of red cells. The red-blood cells often contain granules staining with basophile dyes and indicating incomplete disappearance of the nucleus; this change may present itself before any other symptom but occurs also in other forms of anæmia. The anæmia is often very marked, and is sometimes the chief or only symptom of lead poisoning; according to some authorities, it is present in a greater or less degree in the majority of white-lead workers, and it leads to weakness, languor, and in young women often to amenorrhœa. Abortion is very often met with in lead poisoning, and in women employed in lead works who do not show any marked symptoms of disease. The children of parents suffering from lead are often weak and undersized, and a very large proportion of them die in early infancy. In animal experiments it is found that the offspring of a male suffering from lead poisoning are undersized, delicate and of slow growth; in most cases the spermatogenesis in the parent is not affected but some become sterile and the germinal epithelium atrophies (Weller).

One of the commonest symptoms is **Lead Colic,** painters' colic, colica saturnina or colica Pictonum. This generally sets in suddenly, and is accompanied in most cases by obstinate constipation, in a very small proportion by diarrhœa. Paroxysms of the most acute agony are followed by intervals of comparative freedom from pain, but in these intervals some tenderness of the abdomen may be complained of, while during the attack pressure generally relieves the pain. The colic lasts for several days, or a week, and then disappears, but is liable to return at intervals. The abdomen is generally hollow, retracted and hard, and during the acute spasms the patient often gains some relief by lying on his face with the fists pressed against the umbilical region, to which the pain is usually referred. Vomiting is frequently present, the pulse is slow and very hard, especially during the acute crises, while the respiration may be accelerated. The urine is scanty and often contains hæmatoporphyrin.

The cause of lead colic is evidently spasm of the intestine, but it is uncertain whether it arises from action on the muscle or on the ganglionic plexus. It can be induced in animals, and is relieved by atropine. The blood-pressure is raised in man, not only during the spasms, but also in the intervals. This contraction of the vessels, like the slowing of the pulse, is often said to be reflex from the pain, but this seems to be disproved by the fact that it remains during the intervals. Some writers have therefore regarded the colic and its attendant symptoms as due to a vascular spasm, and have supported this by showing that nitrite of amyl, which dilates the vessels, also relieves the colic.

Another common result of chronic lead poisoning is **Paralysis,** lead

or painters' palsy, paralysis saturnina, which is almost invariably limited to certain groups of muscles, the extensors of the forearm. It is bilateral in many cases, but sometimes involves only one arm. The affection generally begins in the middle and ring fingers, which cannot be extended, then spreads to the index and little finger, and afterward to the thumb and wrist. The fingers remain flexed and later the wrist is similarly affected, so that the condition is often known as wrist-drop. Even after all the other muscles of the extensor surface of the forearm are involved, the supinator longus remains normal as a general rule. The muscles affected atrophy rapidly, and in old cases contracture of the flexor muscles sets in, when the limb becomes immovable and has a characteristic claw-like appearance. More rarely other regions are affected, such as the laryngeal muscles (in the horse), the external rectus of the eye, or the muscles of the leg. In animals several observers have succeeded in inducing paralysis of the hind

Fig. 73

Lead palsy of the forearm extensors. (After Oliver.)

limbs, and the legs are said to be affected very often in young children. When paralysis is complete, the reaction of degeneration is given by the muscles on electric stimulation, and even muscles which are not completely paralyzed are said to give it in some cases. The cause of lead palsy is peripheral neuritis and degeneration of the nerves, which sometimes involves secondarily the cells of the anterior horn of the spinal cord. Not infrequently the onset of palsy is very sudden, and this has been ascribed to small hæmorrhages in the nerve trunk. Peripheral neuritis and paralysis have been elicited repeatedly in animals. According to Edinger's view the nerves of those muscles are selected by lead, which are least developed in proportion to the work they have to perform. The afferent fibres are also involved in the action, as is shown by local **Anæsthesia**, which is generally sudden in its onset, but may be preceded by numbness or tickling of the skin, and generally lasts only one or two weeks when sensation returns again to the part.

Lead **Arthralgia**, which arises from the same action on the peripheral nerves, consists in sharp lancinating or boring pains around the joints, the intensity of the pain being comparable only to that of lead colic. It sets in suddenly, usually in the night, and generally disappears as suddenly.

Lead **Amblyopia**, or blindness, is one of the rarer affections. The sight may be lost completely, or may only be dim, and the onset may be sudden or gradual. It arises from neuritis of the optic nerve and degeneration of the retinal nerve cells, or in some cases may be the result of the changes in the kidney occasioning albuminuric retinitis or effusion into the optic sheath. In early cases of neuritis, the disease can generally be arrested and even complete restitution may take place, but if it is neglected, optic atrophy follows.

Under saturnine **Encephalopathia**, a number of disorders of the brain are classed together. They are comparatively rare at the present time, and their onset generally indicates long standing and neglected lead intoxication, although in some cases the patient has been exposed to the poison for only a short period. One of the most characteristic features is the rapidity with which the disease changes from one type to another, and the diversity of the symptoms present at one time. These cerebral symptoms sometimes appear suddenly, while in other cases they are heralded by violent headache, giddiness and sleeplessness, or by amblyopia, deafness, great depression, stupor, weakness, and tremor. Later, sudden mania and delirium, with convulsions resembling chorea or epilepsy, hallucinations and illusions indistinguishable from those of alcoholic delirium, sudden apoplectic paralysis, ataxia, partial analgesia, hyperæsthesia, or coma may occur separately or in succession. Oliver states that the encephalopathic symptoms are especially liable to occur in persons addicted to alcohol.

In animals cerebral symptoms are readily induced by lead in chronic poisoning. Chorea, tremors and general convulsions have been caused in this way in dogs.

The encephalopathia is obviously of cerebral origin, and at autopsy atrophy of parts of the cerebrum, or hæmorrhages and very frequently disease of the brain vessels has been met with. In other cases of undoubted encephalopathia in man, no such lesions have been observed; and many of the symptoms are obviously not due to these gross lesions, for the suddenness of their onset and of the recovery precludes any such explanation, and shows that lead has also a direct action on the brain cells.

Another organ acted on by lead, especially in prolonged poisoning, is the **Kidney**, which is often found to present a typical red granular nephritis. During life the urine presents the ordinary appearances of this disease, being copious in amount and of low specific gravity, and containing comparatively small quantities of albumin or casts. In some cases in man, the kidney has presented a mixture of parenchymatous and interstitial disease, while in animals the parenchyma alone is affected, perhaps because the experiments have not lasted long enough. The disease of the kidney from lead poisoning, as from other

sources, may cause dropsy, uræmia and amblyopia, but the brain and eye may be affected in cases in which there is no nephritis.

Another condition in which lead poisoning may act as a predisposing factor is **Arteriosclerosis** and **High Blood-pressure**; the malnutrition, anæmia, and renal changes induced by the metal would in themselves tend to induce changes in the vessels throughout the body, and degeneration of their walls is met with in a considerable proportion of cases of very prolonged exposure to it.

Gout is said to be common in lead poisoning, which may predispose to this disease, for Garrod states that in one-fourth of the cases of gout treated by him there was a history of lead poisoning; more recently the relationship is less obvious. The purine substances of the urine are augmented in chronic lead poisoning in animals.

Lead poisoning runs no definite course. As a general rule the anæmia, wasting, constipation and weakness appear early, and then colic may follow, or paralysis, or arthralgia. Nephritis, encephalopathia, anæsthesia and gout are rarer, and as a rule occur only in very prolonged poisoning. Any one of these symptoms may be present alone, and the diagnosis is then very difficult. In doubtful cases the urine or the stools may be tested for lead. Every case in which lead is found in the urine is not necessarily one of lead intoxication, however, for it has been detected in a number of perfectly healthy individuals.

It is impossible at present to give any general explanation for the diversity of the forms of chronic lead poisoning. The central nervous system is certainly acted on, both in its higher and lower divisions. The lead line, metallic taste and nausea, and perhaps the constipation, would seem to be connected with the excretion of the metal along the alimentary canal, while the renal action is probably of the same nature as that inducing periarteritis in the brain and, as is alleged, in the lungs under some conditions.[1] The anæmia indicates an action on the red cells of the blood, and the gout some disturbance of the general nutrition. Attempts have been made to elucidate the nature of this action on metabolism by estimating the urea and other constituents of the urine, but no important light has been thrown on it by this means, nor in fact are significant results to be hoped for in a disease which offers so many and so diverse types as lead poisoning. In chronic poisoning lead is found deposited in the liver and other organs, but the quantity actually in circulation at any one time may be so small as to entirely escape estimation; the symptoms and lesions of chronic lead poisoning are thus not due to the accumulation of lead in the affected organs but to the cumulation of injury from its continually renewed passage in infinitesimal dilution (Straub).

Lead acts upon so many tissues that it might be expected to have some distinctive action upon the simpler organisms, but, as a matter of fact, it seems less poisonous to them than most other heavy metals.

[1] Some authorities are disposed to regard the action on the vessels as the fundamental feature in lead poisoning which leads to all the other symptoms; thus the colic is said to be a vascular spasm and the encephalopathia and palsy to arise from capillary hemorrhages.

Organic Lead combinations have been investigated in the hope that their action might throw light upon that of the metal. Triethyl lead ($Pb_2(C_2H_5)_3$) has been examined by Harnack and more recently by Mason, in the hope that it might be decomposed in the tissues to simpler lead compounds, but the effects seem to arise from the unaltered molecule, and cannot be brought into analogy with those of the metal. In the frog it induces paralysis apparently from action on the central nervous system. In the dog small doses cause a marked fall in blood-pressure, with marked disturbance or failure of the respiration, but a second dose increases the blood-pressure by constriction of the vessels and accelerates the respiration. The intestinal movements are increased, perhaps from central action. Tremors and convulsions may occur from stimulation of the brain.

Preparations.

Plumbi Acetas (U. S. P., B. P.), lead acetate, sugar of lead ($Pb(C_2H_3O_2)_2+3H_2O$), forms colorless crystals, with a sweetish, astringent, afterward metallic taste, very soluble in water, less so in alcohol. 0.06 G. (1 gr.); B. P., 1–5 grs.

Pilula Plumbi cum Opio (B. P.), contains about 12 per cent. of opium. 2–4 grs.

Liquor Plumbi Subacetatis Dilutus (U. S. P., B. P.), lead water, Goulard's lotion or water, an alkaline solution containing about 1 per cent. of the subacetate.

Lead plaster or diachylon plaster, *Emplastrum Plumbi*. (See Mechanical remedies, p. 677.)

Therapeutic Uses.—Lead is used in therapeutics only for its astringent action. The acetate is prescribed internally in diarrhœa, generally along with opium, and always in pill form, as the solution would act on the stomach and have less effect on the bowel. It has been tried in dysentery and cholera, but has proved of little value. Lead has also been advised in cases of hæmorrhage from the lungs, kidneys and uterus, but is quite valueless here, as it acts as a styptic only when applied locally. Still less reason is there for its use in nephritis, cystitis, and similar conditions.

Externally, a solution of the acetate or the dilute solution of the subacetate is used as an astringent lotion in burns and as an injection in gonorrhœa.

Lead ought not to be employed externally or internally except for a short time as otherwise symptoms of poisoning may arise.

Poisoning.—In chronic poisoning, the general treatment is the removal of the patient from the danger of further exposure and nutritious, strengthening diet. Potassium iodide, magnesium sulphate and calcium sulphide are often used in the treatment, and there is some experimental evidence in favor of this; it is unknown how they act, but in the case of magnesium sulphate the improvement is attributed to its purgative effect, at any rate in part (Hanzlik). Diuretics may be prescribed, and hot baths; sulphur baths are especially recommended, and massage is said to hasten the elimination of the poison.

In colic, morphine or opium is often necessary to allay the pain. Belladonna or atropine is used less frequently, and nitrite of amyl is said to be efficient for a short time. In the intervals between the paroxysms, a saline cathartic is often necessary to relieve the consti-

pation, or if the vomiting prevents this, a large enema may be thrown into the bowel.

In arthralgia, the pain may necessitate the giving of opiates. In anæsthesia and encephalopathia, the treatment is expectant and symptomatic; for instance, in mania, or violent delirium, chloral may be necessary.

In paralysis, strychnine may be used along with the general treatment, but the chief reliance is to be placed on the electrical stimulation of the paralyzed muscles, first with the galvanic current, and, as recovery sets in, with the induction coil. Massage of the muscles is also of benefit.

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V. COPPER.

Copper seldom gives rise to poisoning, and is less frequently used in medicine than many of the other heavy metals. The soluble salts precipitate proteins from solution, and are therefore astringent when applied to the mucous membranes and to wounded surfaces. In larger quantities they are somewhat irritant and corrosive, although less so than mercury.

Symptoms.—The copper salts have a harsh, metallic, astringent taste, and when swallowed in some quantity cause nausea, salivation, and vomiting. The most of the salt is thus removed, and no further symptoms are observed. Large quantities, however, induce corrosion of the

walls of the stomach and intestine, and give rise to violent vomiting and purging, the copper giving a blue or green color to the vomited matter and the stools, and blood appearing in them later from the corrosion of the mucous membrane. Violent pain in the abdomen is complained of, and the usual symptoms of acute corrosive poisoning may follow—collapse, with weak pulse and respiration, headache giddiness, unconsciousness, delirium, coma, convulsions, and paralysis. These may prove fatal in a few hours, but more frequently the patient, lives for several days to sink eventually from exhaustion.

The nausea, vomiting and purging of acute copper poisoning are due to the local effect on the mucous membranes of the stomach and intestine. In fact, although some copper is absorbed in these cases, there is no reason to suppose that any of the acute symptoms are due to it, for they are all induced by other poisons which act only as gastro-intestinal irritants.

The occurrence of **chronic copper poisoning** in man has not been established. In copper and brass workers, gastro-intestinal catarrh, or colic and diarrhœa, occur occasionally and are ascribed to the copper swallowed in the course of their occupation. The dust inhaled may similarly cause laryngeal irritation and bronchitis. The skin and hair have often a greenish tint, and a green line on the teeth, just where they enter the gums, is known as the copper line; but it is believed that these are due largely to the copper dust deposited on the skin, hair and teeth, and not to the excretion of the metal. Local paralysis, anæmia, tremor, emaciation and cutaneous eruptions are said to have followed these symptoms in some cases, but it may fairly be doubted whether these symptoms are really due to the copper or to the lead, arsenic and other poisons often associated with it. Furthermore, copper has been taken in the form of the metal, or of its soluble salts, for prolonged periods without any symptoms being elicited except those of slight intestinal catarrh and some nausea. Animals have been fed with food containing large doses of copper for many months, apparently without any symptoms of poisoning, and copper is found so regularly in the tissues of man and animals that it may be regarded as a normal constituent, although its function is altogether unknown and it may be merely stored up on its way to excretion.

In animals the general action may be elicited by the injection of slowly dissociated salts, such as sodium-copper tartrate into the blood or subcutaneously. In the frog copper induces great weakness and eventually complete paralysis of the spontaneous movements and of the heart. This appears to arise from a depressant action on the central nervous system, but the muscles are also weakened and finally completely paralyzed; often fibrillary contractions are observed early in the frog, but it is unknown whether these are of central or of peripheral origin. The heart is somewhat accelerated at first by very small quantities, but later becomes slow and weak, and finally ceases in diastole before the skeletal muscles are paralyzed; the changes in the heart are due to direct action on the muscle.

In mammals the intravenous injection of copper does not cause vomiting, but the locomotion soon becomes slow, clumsy and weak, and later complete paralysis of the spontaneous movements follows. The heart and respiration seem equally involved, but the respiration ceases somewhat earlier than the heart. The blood-pressure rises slightly after the intravenous injection of copper, but afterward falls, partly on account of the weakness of the heart, and partly from dilatation of the bloodvessels. When an animal survives longer, violent, sometimes bloody, diarrhœa is generally induced by copper, as by most of the other heavy metals. The animals lose flesh rapidly, and refuse food, and the urine often contains albumin, and according to some authors, hæmoglobin and blood. In the rabbit some icterus and anæmia is said to occur from the destruction of the red-blood cells, and fatty degeneration

of the liver, kidney and heart has been observed. Others have found ecchymoses and congestion along the intestine and in the kidney to be the chief lesions. Similar results are obtained in rabbits when copper is given by the mouth, as this animal is incapable of rejecting the poison by vomiting. In the dog, on the other hand, poisonous doses are removed by vomiting when they are given by the mouth.

Copper is absorbed from the intestine, for large quantities have been found in animals fed on it for some time; a large proportion of the poison is absorbed when small doses are given, but the proportion lessens as the dose is increased. It also passes into the blood from other mucous surfaces and from wounds. The copper absorbed from the intestine is lodged chiefly in the liver, less in the spleen, kidney, and thyroid. It is excreted in the bile, urine and saliva, in the intestinal secretions, and in traces in the milk, and is said to pass from the mother to the fœtus in utero. Copper is found in small quantities in these organs and secretions in man and in animals that have not been treated with it, but in much larger amount after prolonged administration.

Copper is found as a normal constituent of the blood in many of the invertebrates, in which it performs the same function as the iron of the hæmoglobin in the vertebrates. It has been detected in one of the pigments of birds' feathers, and, as has been stated, is so frequently found in the tissues of mammals, both wild and domesticated, that it may be regarded as a normal constituent. Oysters and other animals take it up in large quantities when they live in water rich in copper, and apparently are not injured by it, while on the other hand Locke found that the traces of copper contained in the water distilled in copper vessels is sufficient to destroy tadpoles and tubifex, one of the annelid worms. It is sometimes stated that copper solutions sprinkled on their leaves improve the growth of some of the higher plants, but this appears to be incorrect, its only action being to weaken them, though it may compensate for this by destroying parasites. Traces of copper added to the water in which they live, destroy some of the simpler algæ, and the parasites of the grape vine, potato, apple and other plants are killed by spraying the plants with copper; yeast ceases growing in a 0.02 per cent. solution, while the moulds seem to be almost immune to its action. Bucholtz states that the development of bacteria is stopped by a solution of copper sulphate under 1 per cent. in strength, but others find that tubercle bacilli may be suspended for days in a 1 per cent. solution of copper chloride without any impairment of their virulence. Copper thus seems to have a very powerful poisonous action on certain living forms and to be harmless to others, and the subject deserves further investigation. It is possible that it may prove to act prejudicially to some human parasites, and it is certainly less dangerous to man than many other remedies used as parasiticides and disinfectants.

Cupri Sulphas (U. S. P., B. P.) ($CuSO_4+5H_2O$), large, transparent, deep blue crystals, without odor, but with a nauseous, metallic taste, soluble in water, scarcely so in alcohol. Dose as an emetic, 0.25 G. (4 grs.); B. P., 5–10 grs.

Therapeutic Uses.—Copper sulphate is used internally only as an emetic, and for this purpose ought to be given in about 1 per cent. solution. It acts promptly, and does not leave so much depression and nausea as other metallic emetics, and for this reason is unsuitable as an expectorant. In phosphorus poisoning it is especially valuable, as in addition to causing evacuation of the stomach, the metal is deposited on the particles of phosphorus and prevents their absorption.

Externally copper sulphate is used as an astringent injection in gonorrhœa, and occasionally as a lotion in ulcers and wounds; for this purpose it is employed in 1 per cent. solution. The solid crystals are sometimes used to touch exuberant granulations for their astringent and corrosive effect.

Small quantities of copper sulphate have recently been used to destroy the algæ which grow in reservoirs and often give the water a disagreeable odor and taste. The proportion of copper required for this purpose is about one part in a million or sometimes in fifty millions; this treatment does not render the water deleterious to man, for much larger quantities of copper have been taken constantly without injury. It has also been suggested to disinfect water contaminated with typhoid bacilli, and some success has been recorded, though these organisms are less susceptible to copper than those of putrefaction; the proportion of copper required for this purpose appears to be greater than that necessary to destroy the algæ.

The chloride of copper is a much more irritant and disinfectant substance than the sulphate.

In cases of **Poisoning** with copper salts, the stomach generally rejects the metal by vomiting and no emetic is required. Non-corrosive compounds may be formed by giving milk, egg, or other forms of albumin, tannic acid, magnesia, or ferrocyanide of potassium. Morphine may be required for the pain, ice to stop the vomiting.

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VI. ZINC.

The effects of zinc resemble those of copper so closely that they need only brief mention. Like copper, the soluble salts precipitate proteins and therefore possess an astringent action, or in large quantities act as irritants and corrosives. The sulphate is the soluble salt most commonly used in medicine, but the chloride has frequently given rise to corrosive poisoning, and is therefore of greater importance than the chloride of copper. The sulphate is much less irritant and more astringent than the chloride, which is used only as a caustic and disinfectant.

Symptoms.—The sulphate of zinc has a harsh, metallic taste, and in small doses causes nausea and vomiting, in larger quantities violent vomiting and purging, pain in the abdomen and collapse; these symptoms are due to the local action on the stomach and intestine. The

insoluble zinc oxide and carbonate are not liable to cause acute irritation, but their prolonged ingestion has given rise to dyspepsia and constipation or diarrhœa in some cases. The continued administration of zinc salts has no effects in man, except those of disordered digestion and constipation, and Lehmann could detect no effects in the dog after the administration of 155 G. of the carbonate in the course of three hundred and thirty-five days, although a considerable amount of the metal had been absorbed.

In workers exposed to zinc fumes a condition known as brassfounders' ague is occasionally met with. It is ushered in by dryness of the throat, hard cough, metallic taste, constriction of the chest, lassitude and weakness, sometimes with nausea and vomiting; muscle cramps and joint pains are often present, and later prolonged rigors and shivering are followed by a rapid acceleration of the pulse, coughing and soreness of the chest, and headache. These symptoms give place to profuse perspiration, and the patient sinks into a sleep from which he awakes in ordinary health. The attack has been attributed to the absorption of decomposition products of the proteins destroyed by the fumes of zinc inhaled; it is held that the same symptoms would arise from the fumes of other metals, but these are less volatile than zinc and are therefore seldom inhaled. A number of obscure nervous conditions have also been described as arising from zinc in workmen in brass factories and bronze works, but it is questionable whether they are really due to the zinc or to its impurities, such as arsenic and lead.

Action.—The general action of zinc can be observed only when a double salt is injected intravenously or hypodermically, as the ordinary salts precipitate the proteins of the blood when injected into a vein, and cause acute irritation when applied subcutaneously. In the frog, zinc is found to cause weakness and lessened reflex excitability, and the heart becomes weak and inefficient, irregular and slow, and eventually ceases in diastole; the voluntary muscles respond more weakly to the electric current in life and lose their irritability entirely soon after death.

In mammals, the intravenous injection of zinc causes vomiting and diarrhœa, weakness, tremor and paralysis of the extremities; and the stomach, intestines and heart contain small hæmorrhages. The blood-pressure seems to be but little affected, until just before death, but the pulse is slowed. Helpup found that the subcutaneous injection of zinc salts induced congestion and parenchymatous inflammation of the kidney.

Zinc seems therefore to depress the central nervous system and to a less extent the heart and voluntary muscles, and to cause irritation and congestion of the mucous membrane of the stomach and intestine and inflammation of the kidney. The fact that vomiting occurs from the intravenous injection of zinc salts is explained by the metal inducing inflammation in the stomach.

Lehmann found that of the zinc absorbed from the stomach and intestine, most is contained in the liver and bile, less in the spleen, kidney, thyroid and pancreas, and very little in the other tissues. Zinc is excreted by the stomach and intestinal walls, and in much smaller amounts in the bile and urine.

Locke found zinc to possess a poisonous action on the tadpole and tubifex when present in traces in the water in which they lived, but this effect was weaker than that of copper. Richter states that zinc is less poisonous to fungi than copper, and very weak solutions seem to promote their growth The zinc salts seem to be in general much weaker than those of copper, which they resemble closely in other respects.

Preparations.

Zinci Sulphas (U. S. P., B. P.) ($ZnSO_4 + 7H_2O$), colorless, transparent, odorless crystals, with a harsh, astringent, metallic taste, soluble in water, not in alcohol. 1.0 G. (15 grs.); B. P., 10–30 grs.

Zinci Oxidum (U. S. P., B. P.) (ZnO), an amorphous white powder without odor or taste, insoluble in water.

Zinci Carbonas Præcipitatus (U. S. P.), *Zinci Carbonas* (B. P.), a preparation varying somewhat in composition, but always containing some oxide, which it resembles in appearance and solubility.

Unguentum Zinci Oxidi (U. S. P.), 20 per cent.

Unguentum Zinci (B. P.), 15 per cent. of the oxide.

Zinci Chloridum (U. S. P., B. P.) ($ZnCl_2$), a white powder, or porcelain-like mass, irregular or moulded into pencils, odorless and strongly caustic, very deliquescent and soluble in water and alcohol.

Liquor Zinci Chloridi (U. S. P., B. P.), 50 per cent.

The acetate, phenolsulphonate or sulphocarbolate, and the valerianate of zinc are superfluous soluble salts.

Therapeutic Uses.—Zinc sulphate has been used internally as an emetic, but not so widely as the sulphate of copper, although it is equally efficient. The sulphate, the oxide and the carbonate have been advised in the treatment of various brain diseases, from the erroneous belief that zinc is a sedative.

Externally the zinc preparations, with the exception of the chloride, are used as astringents, the sulphate being applied in solution, the oxide and carbonate as powders or ointments. The oxide is especially useful as an application in many skin diseases. Solutions of the sulphate are used as an eye wash (one-half per cent.) and as an injection in gonorrhœa (1–4 per cent.). In the last case it is sometimes formed into a mixture with acetate of lead, the sulphate of lead which results being credited with some astringent action and not being washed off so readily from the diseased surface.

The chloride of zinc differs from the other salts in being a powerful caustic, and is used as a paste or in pencil form to destroy malignant growths, or in chancres and gangrenous sores. It produces a white eschar and is said to be less liable to spread over the surface than potash, but penetrates the epidermis with difficulty, and it is therefore advisable to destroy this with potash or a blister before applying the caustic. It is sometimes mixed with flour or dried gypsum and water to a paste (Canquoin's paste), when a less active caustic is desired. Its use is much more restricted at the present time than formerly. Burnett's disinfecting solution (a somewhat stronger solution than the official liquor) is used to disinfect fæces and urinals, and the liquor of the pharmacopœia may be employed for the same purpose. It has frequently given rise to severe corrosive poisoning from being swallowed accidentally or suicidally.

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VII. SILVER.

The only salt of silver used at all extensively in medicine is the nitrate, which is caustic, astringent, and disinfectant. Added to solutions of proteins, it forms a heavy precipitate, which is at first white in color, but turns darker in the light as the silver is reduced.

Symptoms.—In dilute solution silver is a slight irritant to the skin, and causes redness and itching only, but more concentrated solutions blister, and the solid nitrate of silver causes an eschar, which is at first white, but later turns black from the reduction of the silver in light. On the mucous membranes, dilute solutions act as astringents, but concentrated cause irritation and corrosion. The caustic action of silver does not extend so deeply as that of some other metals, such as mercury, because the penetration of the metal is limited by the formation of the insoluble chloride. On the other hand, the silver salts are more irritant than those of lead.

The astringent action is due to the formation of a protective layer of coagulated albumin. If irritation is induced the vessels are dilated, and there is no evidence that they are ever contracted in the practical use of silver.

In acute silver poisoning from the ingestion of silver nitrate, the symptoms are those of severe gastro-intestinal irritation and corrosion. Burning pain is felt in the throat and abdomen, and is followed by nausea and vomiting and often by purging. The mouth is covered with a grayish-white membrane, which turns darker after a time, but this is absent if the poison is swallowed in the solid form, as has happened sometimes. The corrosion of the stomach and intestine cause collapse, with weak pulse, shallow respiration and pinched features and this may be followed by coma, convulsions, and death. The throat, stomach and intestine presented the ordinary appearances of acute corrosive poisoning in one case in which an autopsy was performed.

Action.—The symptoms of acute poisoning are due to the local action, and present no features suggesting that silver is absorbed and causes general poisoning. The action of silver after absorption has, however, been investigated in animals poisoned by subcutaneous or intravenous injection. The nitrate, owing to its coagulating properties, is unsuitable for this purpose, and the hyposulphite of sodium and silver, or a solution of the albuminate has therefore been used. In mammals the central nervous system is the chief seat of action, especially the medulla oblongata, which seems to be stimulated at first, for the blood-pressure rises and the pulse is somewhat slow, owing to increased activity of the vasomotor and vagus centres. Later the blood-pressure falls and the respiration becomes slow and labored, and eventually ceases from paralysis of the centre. Gaethgens asserts that the diaphragm, and eventually the other striated muscles are paralyzed soon afterwards. The heart is comparatively little affected and often continues to beat some time after the respiration has

stopped. In less acute poisoning, when the animal survives the injection for several hours or days, a marked increase in the bronchial secretion, culminating in œdema of the lungs, has been noted; no satisfactory explanation of this has been advanced, but it does not seem due to cardiac inefficiency. Congestion and ecchymoses are found in the stomach and intestine, and some authors mention ulceration of these mucous membranes. Cohnstein found that small quantities of silver salts injected intravenously cause some increase in the urine for a time, but that larger quantities are followed by albuminuria.

In cold-blooded animals and in invertebrates, silver preparations are said to cause violent convulsions, resembling those of strychnine and followed by general paralysis.

The general action of silver is thus apparently directed first of all against the medulla oblongata, the rest of the central nervous system being affected to a less extent. The mucous membrane of the stomach and intestine is acted on, as by most heavy metals, and the kidney is also liable to irritation. Œdema of the lungs occurs frequently.

Chronic Poisoning.—There is no evidence that in acute poisoning in man any considerable amount of the metal is absorbed from the stomach and intestine. When silver is given for prolonged periods, however, some is absorbed, although probably only a minute fraction of that actually swallowed. None of it is found in the epithelium of the stomach and intestine, and some of it may circulate in the blood in a soluble form for a short time. But the greater proportion is very soon thrown down in the form of minute granules, which are found in the connective tissues of the body chiefly, and when present in quantity, give a dark color to the skin and mucous membranes. This pigmentation (Argyria) was much commoner formerly, when the nitrate was used in the treatment of epilepsy. More recently it has occurred in the makers of artificial pearls, who use silver as a pigment. Local argyria is sometimes met with from the prolonged application of silver nitrate to the eye or throat, when it tints the eyelids and mouth, and from working with silver, when the hands are permanently blackened from the granules being forced into the skin.

The deposit of the silver in the skin gives it a darker color, varying from light gray in mild cases to a darker slate shade after more prolonged use. It is generally distributed all over the body, but in some cases has been especially marked in the face, and it is said to begin in the gums, where it causes a dark, slate-colored line somewhat resembling the lead line. In the skin it is found in the corium, not in the epidermis. The deposit and the dark color extend throughout the alimentary canal and the respiratory passages, the granules occurring in the connective tissue, particularly in the intestinal villi, and not in the epithelium. The glomeruli of the kidneys, the connective tissue of the liver and spleen, the choroid plexus, the tunica intima of the aorta, the serous membranes, and the mesenteric lymph glands contain more of the deposit than other organs. The pigmentation is not accompanied by any other symptoms of importance, and the victims live to old age without suffering from the chronic poisoning in any way, except from the annoyance induced by the change in color.

Argyria is quite incurable, although many attempts have been

made to remove it. Iodide has been tried, for the most part without effect, and blistering is equally valueless, as the pigment lies deeper than the epidermis. The only known solvent of the granules is cyanide of potassium, and of course this is inadmissible, owing to its powerful poisonous action.

Argyria has been induced in animals by prolonged treatment with small doses of silver salts, though here the pigment is not found in the skin, but in the connective tissue of the internal organs.

In man it seems likely that most of the silver passes through the alimentary canal unabsorbed and that the small proportion taken up by the tissues is precipitated and remains embedded in them indefinitely, for the pigmentation remains unchanging in its depth, and there is therefore no reason to suppose that any of the silver is eliminated.

In animals, however, some of the silver injected hypodermically or intravenously is excreted by the epithelium of the alimentary canal. None appears in the urine. In the frog silver injected hypodermically is all excreted by the epithelium of the tongue, is swallowed, and passes out in the fæces. No other poison is known to be eliminated by this channel.

Silver nitrate is a powerful disinfectant, partly from its action in coagulating the proteins of the microörganisms, partly from the specific effects of the metal.

Preparations.

Argenti Nitras (U. S. P., B. P.) ($AgNO_3$), colorless crystals which become gray or grayish-black on exposure to light in the presence of organic matter, with a bitter, caustic, strongly metallic taste, very soluble in water, less so in alcohol. 0.01 G. ($\frac{1}{6}$ gr.); B. P., $\frac{1}{4}$–$\frac{1}{2}$ gr.

Argenti Nitras Fusus (U. S. P.), moulded nitrate of silver, lunar caustic —a white, hard solid, generally cast in the form of pencils.

Argenti Nitras Induratus (B. P.), toughened caustic, silver nitrate fused with 5 per cent. of nitrate of potassium.

The silver preparations ought to be kept in dark amber-colored bottles, in order to prevent their being reduced by light, and ought not to be prescribed with organic matter, which rapidly reduces them.

Therapeutic Uses.—Silver nitrate pills have been recommended in some forms of dyspepsia and vomiting, and in gastric ulcer, and have also been used as astringents in diarrhœa, but generally with little benefit. A very ancient use of silver oxide and more recently of the nitrate, is that in the treatment of epilepsy, chorea, tabes and various other nervous diseases. This dates from the Arabs, and is said to have originated from the astrological medicine of that period, which taught that nervous diseases were especially affected by the phases of the moon, which was associated with silver in their system (hence lunar caustic, lunacy). Clinical experience shows that silver is of no benefit in epilepsy, and, in fact, it is improbable that silver reaches the central nervous system in any other form than inert granules. This use of silver often gave rise to argyria without benefiting the patient, about 15–30 G. proving sufficient to cause marked pigmentation.

Externally silver nitrate is employed very extensively, the sticks of lunar caustic being used to destroy warts and other small skin growths, to arrest capillary hæmorrhage, to destroy the false membranes of diphtheria and for other similar purposes. A solution of 2–5 per cent. may also be applied to cauterize chancres and indolent ulcers, and one of 1–2 per cent. may be painted on mucous membranes as an irritant disinfectant; a solution of common salt is then used to wash the part, in order to remove the excess of silver. In ophthalmia, especially of the infectious form, a solution of 1–2 per cent. is extremely valuable, and, in fact, a routine treatment in some lying-in hospitals is to wash the eyes of the infant with this solution immediately after birth as a prophylactic measure to prevent ophthalmia. A solution of this strength is only to be used by the surgeon himself, and the eye should be washed out with a salt solution at once. A more dilute solution (one-fourth to one-half per cent.) may be used as a lotion for the eye more frequently, may be applied to extensive denuded surfaces, as burns, and is often thrown into the rectum in chronic dysentery. In gonorrhœa, the nitrate of silver, 1 part in 500–2,000 of water, is used as an injection, and is found to have great value, destroying the gonococci and promoting healing. Stronger solutions (up to 5 per cent.) have been used to abort the disease in its onset, but cause great pain.

The precipitation of silver nitrate by proteins and chlorides confines its disinfectant action to narrower limits than those of some other bactericides, and this has led to the introduction of a number of other compounds, which are less easily dissociated and accordingly less liable to be thrown out of solution. Thus *argentamine*, a 10 per cent. solution of silver phosphate in 10 per cent. ethylendiamine solution, has been used, in gonorrhœa diluted to 1:1,000–5,000, in the eye in 5 per cent. solution. Another recent product is *argonin*, which is a combination of casein and silver, is soluble in water, and, like argentamine, is not precipitated by chlorides nor by albumin; it is a somewhat weaker disinfectant than the nitrate and argentamine. The lactate of silver, *actol*, and the citrate, *itrol*, have also been used as disinfectants. The former is used in solution (½ per cent.), the latter as a disinfecting powder in wounds. *Protargol*, *largin*, *argyrol* and many other compounds of silver have been introduced, but the best known in the last few years has been Credé's *colloid silver* (*Collargol*), which is metallic silver in colloid form, which may be suspended in water (4 per cent.) or in ointment (10–15 per cent.). This has been advertised as a bactericide in the most diverse conditions, and has been injected hypodermically, and even intravenously, to destroy microbes in the tissues. But it has no disinfectant action, and in fact is a very inert body, which is devoid of any therapeutic properties. It may be added that none of these newer preparations are superior to the nitrate in efficiency as disinfectants, and those that are less irritant are also less reliable.

In cases of poisoning with silver nitrate, eggs, milk and, above all, common salt solution are indicated to form insoluble compounds. In argyria no improvement can be expected, though the iodide of potassium may be tried.

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VIII. BISMUTH.

The insoluble salts of bismuth, in especial the subnitrate, have long enjoyed a reputation in the treatment of gastric and intestinal irritation, and have more recently been advised in surgery as applications to granulating wounds.

Symptoms.—Taken in therapeutic doses, the subnitrate induces no marked symptoms, even after prolonged use. It has little or no taste, and passes through the stomach and intestine for the most part unabsorbed. It does not seem to affect the passage of food through the stomach in most cases, but is believed to lessen the secretion of acid under some conditions. In the intestine it often causes some constipation. It gives the stools a black color, which is generally believed to be due to the formation of the sulphide of bismuth, but which Quincke ascribes to the reduction of the subnitrate in the intestine.

Very little of the bismuth swallowed is absorbed, but several authorities have found traces in the urine of patients treated with it internally, so that some evidently passes into the blood under certain unknown conditions. Enormous quantities have been administered internally without any symptoms of poisoning being elicited, but in one or two cases some stomatitis has been remarked, while in other instances large concretions of bismuth have been found in the stomach and bowel.[1] Some of the older writers describe serious poisoning from bismuth, but this was not due to the drug itself, but to the lead, arsenic, or antimony with which it was contaminated.[2] Since its use was extended to wounded surfaces, several cases of serious intoxication have occurred. The symptoms are salivation, swelling of the gums, tongue and throat, pain and difficulty in swallowing, black spots in the mouth and throat, and gangrene of the soft palate and other parts of the mucous membrane of the mouth. Vomiting, diarrhœa and albuminuria follow, but the patients generally recover when the dressing is removed from the wound. In these cases much less bismuth is applied than is often prescribed for internal use, so that it would appear that it is absorbed more rapidly from granulating surfaces than from the mucous membranes, or that what is absorbed from

[1] Large quantities of bismuth subnitrate have been given by the mouth or rectum in Röntgen-ray examination of the stomach and bowel, and in a few cases fatal poisoning has occurred from nitrites being formed from the nitrate and leading to the formation of methæmoglobin in the blood cells. This danger may be avoided by using the carbonate instead of the subnitrate.

[2] A symptom formerly noted in cases treated with bismuth was an extremely disagreeable odor in the breath, but this has been shown to be due to the presence of tellurium in the preparation.

the stomach and intestine is prevented by the liver from reaching the general circulation.

Action.—The general action of bismuth has been studied in animals by the subcutaneous or intravenous injection of the double salts, such as the tartrate of bismuth and sodium. In frogs the symptoms are those of stimulation of the spinal cord and medulla oblongata, followed by depression and paralysis.

In mammals also large doses act chiefly on the central nervous system. The respiration is accelerated, the heart slowed, and violent clonic and tonic convulsions follow at short intervals, during which the movements are weak and incoördinated. Towards the fatal issue of the injection the heart often ceases entirely for some time and then regains its former rhythm quite suddenly. The blood-pressure falls, partly owing to the weakness of the heart, partly from depression of the vasomotor centre.

Smaller quantities injected intravenously or subcutaneously into mammals induce a more chronic form of intoxication, which resembles that seen in man. The earliest symptoms are loss of appetite, vomiting and diarrhœa, salivation and stomatitis with ulceration of the gums, tongue, and buccal mucous membrane. Weakness, slowness and incoördination of the movements follow, and except in very few chronic cases, tetanic convulsions occur at intervals. The urine contains albumin and casts. The weakness gradually deepens into complete paralysis and the animal dies, generally without convulsions. The heart seems little affected in the chronic intoxication, but the blood-pressure is low from the intestinal irritation and general collapse.

Besides the stomatitis and ulceration of the mouth, the post-mortem appearances in chronic bismuth poisoning in animals consist in some congestion, inflammation and necrosis in the kidney, and an intense black coloration of the cæcum and the upper part of the large intestine. This pigmentation is limited very exactly by the ileocæcal valve, and extends throughout the thickness of the bowel wall. The mucous membrane may also be necrosed in places and ulcers and hæmorrhages are met with in it. The black coloration is due to a deposit of bismuth sulphide on the mucous membrane and in the capillary vessels and lymph spaces. Meyer and Steinfeld found that bismuth is excreted all along the alimentary canal, but in larger quantities in the cæcum and large intestine than elsewhere, and they ascribe the ulceration to the precipitation of the sulphide in the vessels and the consequent arrest of the blood current. When sulphide solution was artificially introduced into the stomach and small intestine, bismuth caused necrosis and ulceration here also, so that there is considerable support for this view.

They found bismuth to be stored in considerable quantity in the liver and to be excreted by the urine, stomach and intestine, but especially by the cæcum and large bowel. It has been found in the saliva by other observers, and perhaps in traces in the milk, although the last is not satisfactorily established

The action of bismuth in acute poisoning in animal experiments seems therefore to be exerted on the medulla and spinal cord, to a less extent on the heart, while in chronic intoxication the organs affected are those by which it is excreted —the mouth, kidney, large intestine, and cæcum.

Preparations.

Bismuthi Subnitras (U. S. P., B. P.), white bismuth, Magisterium Bismuthi, bismuth oxynitrate, a heavy, white, insoluble powder, odorless and almost tasteless, with a slight acid reaction. It consists of a mixture of the hydrate and subnitrate of bismuth in varying proportions. 0.5 G. (8 grs.), B. P., 5–20 grs., in powder or suspended in water.

Bismuthi Subcarbonas (U. S. P.), *Bismuthi Carbonas* (B. P.), bismuth oxycarbonate, a white or pale yellowish-white powder, varying in composition; odorless, tasteless, insoluble in water or alcohol. Dose as for subnitrate

Magma Bismuthi (U. S. P.), milk of bismuth, is a suspension of bismuth hydroxide and subcarbonate in water. Dose, 4 mils (1 fl. dr.).

Bismuthi Salicylas (B. P.), *Bismuthi Subsalicylas* (U. S. P.) the salicylate, or oxysalicylate, of bismuth, is a white, amorphous powder, insoluble in water. 0.5 G. (8 grs.); B. P., 5–20 grs.

The *citrate, betanaphtholate,* and *subgallate* of bismuth have been suggested in similar doses, but have no advantages over the better known salts; the only soluble preparation which has been introduced is the *double citrate of bismuth and ammonium* (2 grs.).

Therapeutic Uses.—Bismuth has been used chiefly in gastric catarrh and ulcer, and has often been looked upon as a specific in the last affection, though it acts simply as a protective powder with perhaps some astringent properties. It has been found that when swallowed it is at first deposited in the most dependent part of the stomach, but is later distributed evenly over the surface and forms a continuous sheet over any ulceration, which it thus protects from mechanical injury from the food, and also from the chemical action of the gastric juice. The subnitrate is the only one of the official preparations largely used for this purpose, and is generally administered in quantities of 2–3 G. (30–45 grs.) per day in powder. Recently the use of much larger quantities (10–15 G., 150–250 grs., per day) has been recommended. Bismuth has also been used in diarrhœa for its astringent and protective action on the intestine, which is again due to its being deposited on the mucous membrane and acting as a mechanical coating over irritated surfaces. If bismuth is prescribed with alkalies, the carbonate should be used, as the subnitrate is slightly acid in reaction.

The subnitrate has been advised in surgery as an antiseptic, astringent powder to replace iodoform. It is true that it is devoid of the disagreeable odor of the latter, but it is not a harmless remedy, as was at first supposed, for several cases of bismuth poisoning have been recorded from its surgical use. Like iodoform, its value depends not so much on its germicidal action as on its absorption of the fluids of the wound, which renders the surface less suitable for the growth of bacteria. The therapeutic uses of the bismuth preparations then are largely due to their insolubility. The subnitrate is generally used, the carbonate less frequently, while the soluble double citrate is quite superfluous.

Bismuth is nearly related to antimony and arsenic in its chemical properties, and this has suggested its use in protozoal infections; some favorable results have been recorded from the intramuscular injection of sodium-bismuth tartrate in syphilis and trypanosomiasis; my own experiments on animals gave no encouragement to its use.

Several new compounds of bismuth have been introduced in therapeutics of late years, chiefly with the intention of combining the astringent properties of bismuth with the antiseptic action of benzol preparations. Among these may be mentioned the *salicylate* and *benzoate,* which have been used as intestinal antiseptics and astringents. Others are *airol* (bismuth oxyiodide gallate), *thioform* (bismuth dithio-salicylate) *bismuth phenolate, cresolate, orphol* (β-naphtolate), *xeroform* (tribromphenolate), *tannate, sulphocarbolate, dermol*

(chrysophanate), *eudoxin* (tetraiodophenolphtaleinate). These have been used chiefly as dusting powders in various forms of skin disease, in burns and ulcers, in some ophthalmic conditions and after operations.

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IX. ALUMINIUM AND ALUM.

The chief pharmacopœial preparation of aluminium is the sulphate of aluminium and potassium, or alum, which has been largely used for its astringent properties. Alum solutions precipitate proteins in the same way as the salts of the other heavy metals, and dilute solutions have thus an astringent action, while larger quantities and more concentrated solutions act as irritants. This is more especially the case when dried alum is applied, for, in addition to its coagulating effect on the proteins, this preparation has a great avidity for water.

Symptoms.—Alum solutions have a sweetish, astringent taste, and in small quantities induce no symptoms except a feeling of dryness and astringency of the mouth and throat, and some constipation. Larger doses act as gastric irritants and cause nausea and vomiting, and, in extreme cases, purging. Even the largest quantities, however, are followed by no symptoms except those of gastro-intestinal irritation and inflammation, and the long-continued use of alum does not elicit any symptoms of chronic poisoning. The aluminium salts are only absorbed in small quantity from the stomach and intestine, so that no symptoms of general poisoning arise from the internal use of the salt. Aluminium vessels may be used for cooking, or even to contain acids, without danger of intoxication, as has been shown by a recent series of investigations. The small amount of aluminium absorbed is stored up in the liver, kidney, muscles and pancreas and slowly excreted in the bile and urine.

Aluminium salts, especially the acetate, chloride and some more recent preparations, have considerable antiseptic power, much more than some of the more generally used antiseptics, such as boric acid.

Action.—Aluminium has a very remarkable general action when it obtains access to the blood. In Siem's experiments on animals, the sodium-aluminium lactate or tartrate induced a very slow intoxication, mammals never dying from the effects sooner than one or two weeks after the intravenous injection of the salts. In frogs the symptoms were those of a descending paralysis of the central nervous system, the heart and the peripheral nerves and muscles being little affected. In mammals the first symptoms appeared only after three to five days, and consisted in constipation, rapid loss of weight, weakness, torpor and vomiting; marked abnormalities in movement and sensation were observed later, such as tremor, jerking movements, clonic convulsions, paresis of the hind legs, anæsthesia of the mouth and throat, and lessened sensation all over the body. Before death, diarrhœa often set in, and albuminuria was generally present. The mucous membrane of the stomach and

bowel was found swollen and congested, the kidney and liver had often undergone fatty degeneration, and hæmorrhages were found in the renal cortex. Aluminium was found in the urine.

Like the other members of the heavy metal series, aluminium therefore acts on the bowel and kidney in general poisoning, while many of the symptoms point to a direct action on the brain. Döllken has recently confirmed Siem's results and showed that the nerve cells and fibres of the cord and medulla undergo degeneration, particularly those of the lower cranial nerves.

A metal which is very nearly related to aluminium in its effects in the organism is **Beryllium.** It differs chiefly in being more poisonous, in being absorbed from the stomach and intestine, and in causing more distinct lesions in these when it is injected into the blood.

Preparations.

Alumen (U. S. P., B. P.), alum, potassium or ammonium alum ($AlK(SO_4)_2 + 12H_2O$, or $AlNH_4(SO_4) + 12H_2O$), large, colorless, octahedral crystals, with a sweetish, strongly astringent taste, soluble in water, but not in alcohol. 0.5 G. (8 grs.); B. P., 5–15 grs.

Glycerinum Aluminis (B. P.), 10 per cent.

Alumen Exsiccatum (U. S. P., B. P.), burnt alum, dried alum ($AlK(SO_4)_2$, or $AlNH_4(SO_4)_2$), a white, granular powder, attracting moisture on exposure to air, soluble in water.

Uses.—Alum is used chiefly externally for its astringent properties. It has been employed as an emetic, but is less reliable than the sulphate of copper or tartar emetic, and very large doses (4–8 G., 1–2 drs.) are required. In diarrhœa alum is sometimes advised.

Alum solution is useful as an astringent gargle (1–5 per cent.), as an injection in gonorrhœa ($\frac{1}{2}$–1 per cent.), as an astringent lotion in skin diseases (1 per cent.), and for other similar purposes. Dried alum is more caustic, from its withdrawing fluid from the tissues; it has been used as an application to exuberant granulations, hæmorrhoids, or condylomata, and as a styptic in bleeding from the nose or teeth. A solution (1 per cent.) has been injected into the rectum in chronic dysentery, but is inferior to the nitrate of silver.

A large number of aluminium preparations have been introduced as antiseptic astringents. Among these may be mentioned *alumnol* (naphtol sulphonate of aluminium), *salumin* (salicylate), *tannal* (tannate), *gallol* (gallate), *boral* (borotartrate), *cutol* (borotannate), *alsol* (acetate), *alkasal* (salicylate of potassium and aluminium. They are used partly in solution, chiefly as dusting powders.

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X. MINOR METALS.

Gold.

Gold has never been largely used in therapeutics, although repeated attempts have been made to introduce it in the treatment of the most diverse conditions:

the salt employed has almost invariably been the double chloride of gold and sodium. It is less poisonous than many of the other metals, and may be taken for many months without entailing any untoward symptoms. The subcutaneous injection in frogs is followed by paralysis of the central nervous system, gold possessing little action on the heart and striated muscles in these animals. Injected intravenously in dogs, it causes vomiting and dyspnœa, which soon pass off, but if sufficient has been injected the animal suffers from nausea, vomiting and diarrhœa for several days, eats nothing, loses flesh rapidly, and dies a week or more after the experiment. Numerous ulcers are found in the stomach and intestine, and these often betray their presence in life by hæmorrhages. Gold lowers the blood-pressure somewhat on intravenous injection, probably from the dilation of the mesenteric vessels accompanying the intestinal action. It has little effect on the rate of the heart except in large doses, and dilates the vessels when perfused through them. When given by the mouth to dogs and cats, it is at once ejected from the stomach by vomiting.

Gold has therefore the ordinary general effects of the heavy metals in causing acute irritation and ulceration of the alimentary canal. It tends to accumulate in the spleen and is slowly excreted in the urine and fæces.

Gold has been used in various nervous disorders, in particular in those of a hysterical nature, and may conceivably be of value through suggestion, if the patient be informed of the nature of the remedy. Of late years it has been widely advertised as a specific in chronic alcoholism, but analysis has shown that no gold was contained in the fluid advocated, and there is no reason to suppose that it is of value except by means of suggestion. It has no value in the treatment of tuberculosis.

Platinum.

Platinum resembles gold in its action, but is more poisonous. In the frog it paralyzes the central nervous system and later the striated muscles. Kebler observed a stage of convulsions precede that of paralysis, the spasms evidently arising from the spinal cord or medulla oblongata. In mammals the symptoms resemble those of gold poisoning in almost every detail. Small quantities of platinum double salts injected intravenously increase the urine to some extent; larger injections cause albuminuria.

Platinum, like gold, was at one time advised in syphilis, but has never been widely used.

Chromium.

Chromium is used in medicine in the form of chromic acid and the bichromate of potassium, which are both powerful oxidizing bodies in addition to their poisonous action as metallic oxides. The former property renders them more irritant and corrosive than most of the salts of the heavy metals. Chromic acid in particular is a powerful caustic, combining the action of a metallic oxide, an acid and a strongly oxidizing agent. Applied to the skin in substance it corrodes it, but is said to cause less pain than the more penetrating caustic potash. Even in dilute solution, the chromic salts and the acid act as skin irritants, and the caustic effects are shown by skin diseases, and particularly by deep, perforating ulcers in persons exposed constantly to the dust of chromic salts in factories. These ulcers arise from any abrasion of the skin, and the cartilaginous septum of the nose is also a common seat of ulceration, which eventually leads to perforation. They are due to the local action of the poison and not to its absorption; they are said to be almost painless. The inhalation of the dust leads to chronic bronchitis, while that swallowed and absorbed may give rise to nephritis.

Symptoms.—In acute poisoning, when a large quantity of the acid or of a salt is swallowed, the symptoms are those of gastro-intestinal corrosion, intense pain in the throat and stomach, vomiting and purging, with blood in the vomited matter and the stools, collapse, and frequently death. The mouth and throat

are stained yellow, and the stomach and intestine exhibit the usual appearance of violent corrosive poisoning.

The general action of chromic preparations may be elicited in animals by subcutaneous or intravenous injection, or by the administration of smaller quantities by the mouth. The symptoms resemble those caused by the general action of other metals. In the frog increasing weakness, tremor, and eventually paralysis of the central nervous system are induced. In the mammal weakness and slowness in the movements is followed by albuminuria, glycosuria, diarrhœa, and vomiting. Sometimes twitching of the muscles or even convulsions are seen, and then the weakness passes into general paralysis. The heart seems little affected by chromium, but the blood-pressure falls. After death the stomach and bowel are found congested, and the mucous membrane is necrosed and ulcerated in some parts, covered with ecchymoses in others. Hæmorrhages are also found in other organs of the body, notably in the heart wall. The kidney is in a state of acute parenchymatous nephritis and may contain deposits of uric acid; albumin, casts, and often blood cells appear in the urine. In chronic poisoning interstitial nephritis is said to occur.

Chromic acid and its salts are readily absorbed from the stomach and intestine. They seem to be excreted for the most part through the kidney, to a less extent by the intestinal epithelium probably. In the urine the metal occurs in part in organic combination.

Acidum Chromicum (B. P.), *Chromii Trioxidum* (U. S. P.), chromic acid or anhydride (CrO_3), forms crystals of dark purplish-red color and metallic lustre, odorless, very soluble in water. When brought in contact with organic substances, such as alcohol, glycerin or sugar, it oxidizes them rapidly and often violently with explosion.

Potassii Bichromas (B. P.), bichromate of potassium ($K_2Cr_2O_7$), forms large, orange-red transparent crystals, with a bitter metallic taste, soluble in ten parts of water.

Chromic acid is used as a caustic application to malignant growths, chancres and diphtheritic membranes, to a less extent as an irritant disinfectant. It has generally been applied by dipping a glass rod into a solution formed by allowing the crystals to deliquesce, or it may be fused on the end of a wire. It has also been advised in 5 per cent. solution as an application to prevent perspiration of the feet and to harden the skin.

Manganese.

Traces of manganese are found in the blood and tissues of man and animals very frequently, but this metal is not an essential constituent of the body, but is apparently absorbed accidentally with the food. The salts of manganese in large quantities cause acute irritation of the stomach and intestine, like those of the other heavy metals, and a form of chronic poisoning has been described in workmen exposed to manganese dust; the symptoms are chiefly hysterical laughter or grief, languor and sleepiness and similar psychical manifestations, and later motor disturbances which are exhibited in a spastic gait, tremor and twitching of muscles or cramps and stiffness and increased tendon reflexes. These symptoms are ascribed to lesions of the basal ganglia of the brain and when they are developed, no recovery occurs, although the patient may live many years. Manganese is absorbed from the alimentary tract only in very small quantity, and it appears to resemble iron closely in its course through the tissues. Its general action has been elicited by the hypodermic or intravenous injection of double salts. In frogs manganese injected hypodermically causes a descending paralysis of the brain and spinal cord, and later weakens and arrests the heart, while the peripheral muscles and nerves seem unaffected. In mammals large injections induce epileptiform convulsions, particularly in the rabbit and guinea-pig. Smaller quantities, which cause a less acute intoxication, induce in the dog nausea and vomiting, diarrhœa, weakness, somnolence, stupor, and death from arrest of the respiration. The urine is

often increased, and contains bile pigment, and, toward death, albumin and casts. The stomach and bowel present no congestion or ulceration in these cases. Manganese is found in the vomited matter and the stools, in the liver, kidney and intestinal wall, to a less extent in the other organs. In acute poisoning in mammals the blood-pressure falls, from depression and paralysis of the vasomotor centre, while the heart is affected only much later. In subacute poisoning the darker color of the urine indicates icterus, but this is much more marked when small quantities are repeatedly injected into the subcutaneous tissues, and chronic poisoning induced. In chronic cases the nephritis, which is shown in the acute poisoning by albuminuria, is also more developed, the inflammation commencing in the cells of the tubules but later involving the interstitial tissue, if the animal lives long enough. Manganese injected hypodermically or subcutaneously is excreted chiefly by the intestinal epithelium, to a less extent by the kidney.

Cadmium resembles zinc very closely in its effects, but is more toxic.

Nickel and **Cobalt** salts, administered to the frog, cause a curious dark color in the skin, followed by convulsive movements, which at first arise apparently from the medulla oblongata and higher centres, and resemble those of picrotoxin, but later are reflex, from excessive irritability of the spinal cord. In mammals the usual symptoms arising from the action on the intestine and kidney are accompanied by tremors and chorea-like movements, later by tetanus, and finally by paralysis. These metals also cause a profound fall in blood-pressure resembling that from arsenic and apparently arising from direct action on the walls of the arterioles and capillaries. Strongly acid food may form nickel salts when it is cooked in vessels made of this metal, but no poisoning results, either because the quantity ingested is too small or because it is too slowly absorbed from the stomach and intestine. Cobalt nitrate has been recommended as an antidote in prussic acid poisoning, as it forms an insoluble cyanide, but appears to be of little or no value; the oxide has been applied externally as an astringent antiseptic powder.

Tin salts paralyze the central nervous system in the frog, and later the heart. In mammals diarrhœa, colic, vomiting and general weakness are observed, along with paralysis of some parts of the central nervous system and stimulation of others, leading to ataxia, stiffness and irregularity of the movements, and occasionally convulsions. The sulphide is said to be deposited in the lymph spaces of the intestines in the same way as in bismuth poisoning. General poisoning may be induced by the administration of the salts by the mouth, even when there is no corrosion of the mucous membrane. Tin is often present in preserved foods containing acids, from being dissolved off the vessels, and is certainly absorbed, for it has been detected in the urine after the use of such articles. Apparently it is not often present in sufficient quantities to induce poisoning, for although some cases of "tin poisoning" are met with in medical literature, in none of them has it been satisfactorily established that tin was the cause. Chronic poisoning from this cause is unknown, and animals present no symptoms from prolonged treatment with larger quantities of tin than are contained in any preserved foods.

Thallium salts seem to resemble those of lead in their effects, but have a powerful depressant action on the heart, and are said to be more poisonous. Richet states that the injection of thallium acetate in animals is followed by a general atrophy of the muscles, especially of those of the jaw and spine, while its continued use has caused falling of the hair in man and animals.

Vanadium is said to induce symptoms in workmen in various industries in which it is used. These consist in diarrhœa followed by severe constipation, anæmia, emaciation and some indefinite nervous disturbances; albumin, casts, and blood often appear in the urine. Hæmorrhage from the lungs is not infrequent and lesions are found in the lungs, kidneys, liver, and intestinal tract. The symptoms observed in acute poisoning in animals resemble those induced by the other irritant metallic poisons. Jackson states that the intra-

venous injection of the vanadates in animals causes a sharp rise in the arterial pressure from constriction of the peripheral vessels; this arises from an action on the muscle wall of the arterioles for the most part, though the myoneural junctions may also be involved. The intestinal walls and the bronchioles are similarly aroused to contraction by vanadates.

Molybdenum and **Tungsten** resemble each other closely and induce typical metallic poisoning.

Uranium, in addition to the ordinary features of metallic intoxication, causes some glycosuria, the sugar often amounting to 1 per cent. in the urine. In addition, dropsy occurs in animals poisoned with this metal, partly from the changes in the renal tubules, but chiefly, it is said, from a destructive effect on the smaller vessels.

Selenium and **Tellurium** are classed along with sulphur in chemical systems, but the salts of telluric, selenious and selenic acid induce symptoms resembling those of the heavy metals and arsenic in many points, and may be inserted in this series. In the frog the symptoms are those of central nervous paralysis, and later of heart failure. In mammals vomiting, purging, somnolence, dyspnœa, tonic and clonic convulsions have been noted, and the stomach is found somewhat reddened, the mucous membrane of the intestine swollen and dysenteric, while the kidneys seem less affected. The perspiration is prevented by tellurates, apparently from paralysis of the terminations of the secretory nerves similar to that induced by atropine. An early symptom of poisoning with these bodies is a garlic odor in the breath, and many of the organs are found of a grayish color after death, and possess this odor. Hofmeister has shown that these salts are reduced to metallic selenium and tellurium in the body, and that afterward methyl compounds ($Te(CH_3)_2$, $Se(CH_3)_2$) are formed. These are volatile, and, excreted by the lungs, urine and fæces, give the disagreeable odor. The synthesis of methyl-tellurium is one of the few known cases in which a compound with methyl is formed in the animal body, and is of some biological importance. All the selenium and tellurium is not excreted in this form, for some of it appears in the urine, and probably in the fæces, in other combinations.

Tellurates have been advised in therapeutics to prevent excessive sweating, and certainly have this effect, but are not to be recommended, as the strong garlic odor of the breath persists for days or even weeks after one dose.

Osmic Acid has been recommended as an injection into the nerves in neuralgia. It is an intensely irritant substance, and seems to induce nephritis and diarrhœa when absorbed. The greater part of the poison is, however, deposited as a black powder at the point of injection, owing to its being reduced by the tissues.

Cerium was formerly used in therapeutics in the sickness of pregnancy and similar conditions, but is valueless. The cerium double salts injected into the bloodvessels of animals are said to depress the heart and cause ecchymoses in the stomach and bowel, and nephritis. The oxalate is insoluble and is not absorbed from the alimentary tract.

Thorium is a very inactive metal, which does not seem to be absorbed from the alimentary tract.

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MENSTRUA AND MECHANICAL REMEDIES.

Oleum Theobromatis (U. S. P., B. P.), cacao-butter, a fixed oil expressed from the seeds of Theobroma cacao, forms a yellowish-white solid having a faint, agreeable odor and a bland, chocolate taste. It melts a little below the temperature of the body. Cacao-butter is used almost exclusively to form suppositories, in which astringents and other remedies are incorporated. When introduced into the rectum they melt and the active principle is liberated.

Keratin (not official) is a substance obtained from horns, hoofs, nails, etc., which is insoluble in the gastric juices, but is dissolved by the alkaline pancreatic secretion. It is used to coat pills which it is desired to protect from disintegration in the stomach.

Kaolinum (B. P.), or porcelain clay, is used in the formation of pills containing easily reduced bodies, such as silver nitrate or potassium permanganate. Mixed with the ordinary vegetable excipients, such as confection of roses, or extract of liquorice or gentian, these salts would be reduced at once. Kaolin is an aluminium silicate and forms a soft whitish powder insoluble in water or dilute acids.

Sapo (U. S. P.), **Sapo Durus** (B. P.), hard soap, white Castile soap, is prepared from soda and olive oil.

Sapo Mollis (U. S. P., B. P.), soft soap, sapo viridis, a soap made from potash and olive oil.

Sapo Animalis (B. P.), curd soap, soap made with sodium hydroxide and purified animal fats consisting chiefly of stearin; it contains about 30 per cent. of water.

These soaps are used in therapeutics as ingredients of liniments and plasters. Water containing soap is often thrown into the rectum as an enema, and in infants a soapstick inserted into the anus generally provokes evacuation of the bowels in a few minutes.

Soaps impregnated with antiseptics, such as perchloride of mercury, carbolic acid, tar, or iodine, are often used to disinfect the hands.

The chief preparations in which soap is used in the pharmacopœias are:

Linimentum Saponis (U. S. P., B. P.), soap liniment.

Linimentum Saponis Mollis (U. S. P.).

The liniments consist of alcohol with soap in suspension, perfumed with volatile oils, and are mildly irritant to the skin. They are used largely as bases for other liniments.

The use of the oils, fats and glycerin as vehicles for the application of remedies to the skin has been mentioned already (page 50). They may also be used to dissolve remedies which are insoluble in water, but which are to be given by the mouth, such as phosphorus (in oil).

Plasters are sticky, adhesive substances which are chiefly used to give mechanical support, but which are often impregnated with active remedies in order to elicit their local action on the skin. The basis of many of the plasters is lead plaster, which is obtained by the action of lead oxide on olive oil and consists for the most part of lead oleate.

Emplastrum Plumbi (U. S. P., B P.), lead or diachylon plaster.

Emplastrum Resinæ (U. S. P., B. P.), adhesive plaster.

Emplastrum Saponis (B. P.), soap plaster.

Court plaster is formed from isinglass, the dried swimming bladder of several species of sturgeon, which is dissolved in water, alcohol and glycerin and painted on taffeta. Isinglass differs from lead plaster and its derivatives in being transparent, so that if it is spread on a flesh-colored cloth, it disfigures the hands and face less than the others.

Lead plaster, adhesive plaster and isinglass plaster are used only to cover and protect cuts and abrasions, and to keep the edges of wounds in apposition. The adhesive plaster and isinglass plaster are superior to lead plaster, as they

stick more firmly. It is perhaps unnecessary to add that plasters are always applied spread on cloth.

Another series resembling the plasters in their sphere of usefulness is formed by the **Collodia.** Their basis is pyroxylin, or soluble gun-cotton, which is formed from cotton by the action of sulphuric and nitric acids, and which consists of a mixture of nitrates of cellulose. Collodion is formed by dissolving pyroxylin in a mixture of alcohol and ether. When these evaporate, there remains a fine layer of pyroxylin, which protects the surface to which it is applied and gums the edges of slight cuts together. This collodion is rendered less brittle by the addition of Canada turpentine and castor oil in small proportions, and is then known as flexible collodion. A blistering collodion is formed by the addition of cantharidin to the flexible preparation.

Pyroxylinum (U. S. P., B. P.), soluble gun cotton, colloxylin.

Collodium (U. S. P., B. P.), collodion.

Collodium Flexile (U. S. P., B. P.), flexible collodion.

Collodium Cantharidatum (U. S. P.), *Collodium Vesicans* (B. P.), blistering collodion.

CLASSIFICATION OF DRUGS ACCORDING TO THEIR THERAPEUTIC USES.

Drugs applied for their local action to the skin, wounds, or visible mucous membranes.

Corrosives or caustics

Potash, 549
Mercury nitrate, 636
Silver nitrate, 666
Zinc chloride, 662
Nitric acid and other acids, 561
Chromic acid, 673
Burnt alum, 671
Arsenic, 602
Trichloracetic acid, 562
Ammoniated mercury and other mercury preparations, 636
(Carbolic acid, 139)
(Salicylic acid, 499)

Disinfectants and antiseptics.

General principles, 127-135
Hydrogen peroxide, 144
Permanganate of potassium, 146
Carbolic acid, 135
Corrosive sublimate and other mercury salts, 143
Silver nitrate, 144
Zinc chloride, 662
Boracic acid, 148
Iodine, 153
Iodoform, Iodol, 155
Cresol (lysol), 141
Hypochlorites (Eusol), 156
Chloramine, 156
Tar, 161
Salicylic acid, 142
Picric acid, 142
(Benzoic acid, 501)
(Alcohol, 193)
(Volatile oils (thymol, eucalyptol, etc.))

Astringents.

Tannic acid series, 115
Iron preparations, *e. g.*, sulphate, 647
Bismuth preparations, 696
Lead acetate, 656
Zinc sulphate and oxide, 662
Copper sulphate, 660
Alum, 671
(Alcohol, 193)

Styptics.

Soluble astringents (see above).
Iron perchloride, 648
Silver nitrate, 666
Burnt alum, 671

To contract vessels and reduce hemorrhage and swelling.

Adrenaline, 379

Emollients or protectives.

Emollients, 51
Plasters and Collodia, 677, 678
Dusting-powders — starch, talcum, chalk, and many insoluble metallic powders, which may also be slightly astringent, 53.

Local anodynes and analgesics for pain and itching.

Bicarbonate of potassium, 549
Cocaine, Eucaine, Orthoform, etc., 368–371
Carbolic acid, 135
Chloretone, 242
(Prussic acid, 461)
(Atropine, 340)
(Aconite, 440)
Some volatile oils (in dentistry).

Local anesthetics.

Cold by evaporation of ether, ethyl chloride, carbon dioxide, etc., 74
Cocaine, etc., 368–371

To disinfect rooms and other inanimate objects.

Chlorine, 171
Sulphur dioxide, 170
Formaldehyde, 168
Unslaked lime, 569.
Carbolic acid (crude), 135
Tar, 161
Moist heat.

II. Drugs used for affections of the alimentary tract.

MOUTH AND THROAT (see Section I).

Demulcents, 48
- Chlorates, 150
- Ammonium chloride, 525
- Cubebs, 165

Astringents.
- Tannin group in solution or lozenges, 116
- (Claret, 195)

Antiseptics.
- Boric acid, 148
- Sulphites, 171
- Thymol and other volatile oils.

To lessen salivation.
- Atropine, 338

Flavoring substances.
- Sugars, 53
- Volatile oils series, 65
- Acids (citric), 563
- Syrup of Tolu, Ginger, etc.
- Saccharin, 54

STOMACH.

Digestives.
- Pepsin, Papain, etc., 59, 60
- Hydrochloric acid, 561

Emetics (see p. 445).
- Common salt, 514
- Mustard, 85
- Warm water.
- Apomorphine, 444
- Ipecacuanha, 448
- Tartar emetic, 623
- Copper sulphate, 659
- Zinc sulphate, 662
- (Alum, 671)
- (Ammonium carbonate, 555)

To lessen irritation and vomiting.
- Opium, 262
- Chloral, Chloretone, 241, 242
- Bromides, 270
- Lime-water, 570
- Bismuth, 669
- Cold (ice).
- Carbonic-acid water, 578
- Demulcents, 47
- (Prussic acid, 461)

To lessen acidity, antacids.
- Potassium and Sodium carbonates and Bicarbonates, 550
- Magnesia and Magnesium carbonate, 550
- Lime-water and chalk, 570

To increase secretion, bitters.
- Simple bitters, 55
- Nux vomica, Strychnine, 284
- Cinchona and Quinine, 475

Carminatives.
- Volatile oil carminatives, 61
- Ether, 74
- Alcoholic preparations, 196
- Carbonic acid waters, 578
- Carbonates and Bicarbonates, 550
- Bitters, 55
- Camphor, 69
- Charcoal, 577
- Ammonium carbonate, 555
- Arsenic, 602

INTESTINE.

To promote digestion.
- (Pancreatin, 59)
- (Diastase, 61)

To promote evacuation—purgatives.
- Mild aperients—Castor Oil, Sulphur, Phenolphthalein, 93
- Rhubarb and Aloes group, 95
- Jalap and Colocynth group, 98
- Saline purgatives, 111
- Agar-agar, 110
- Liquid paraffin, 111
- Mercurial purgatives—Calomel and Metallic preparations, 104
- Enemata.
- Glycerin suppositories, 95
- Physostigmine, 356
- Pituitary extract, 397
- Tetrachlorphenolphthalein, 94

To lessen movement and relax spasm.
- Opium and Morphine, 257
- Tannic acid series, 116
- Lime-water, 570
- Lead acetate, 656
- Bismuth, 669
- Atropine (to relax spasm), 340

To destroy parasites—anthelmintics.
- Male fern, 121
- Pelletierine, 123
- Cusso, etc., 122
- Santonin, 125

Calomel, 104
Salol, 162
Thymol, 124
Naphthol, 159
(Some volatile oils.)
(Chloroform, 74)
(Quassia enema, 56)

Disinfectants and antiseptics.

See Discussion, p. 131.
(Vegetable and Saline purgatives.)
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III. Drugs used for their effects on the circulation.

HEART.

To strengthen contraction.

Digitalis group, 430

In auricular fibrillation and flutter.

Digitalis group, 427, 430
Quinidine, 469, 476

To accelerate pulse.

Atropine, 339
(Caffeine, 296)

To slow the pulse.

Digitalis group, 428
(Aconite, 440)

VESSELS.

To contract calibre and raise blood-pressure.

Strychnine, 285
Caffeine, 296
Ergot, 387
Adrenaline (intravenously), 379
Pituitary extract, 397

To relax vessels and lower blood-pressure (angina pectoris).

Nitrite series, 406
Purgatives, 93, 101

To arrest internal hemorrhage.

(see p. 387).
Ergot, 387
Adrenaline, 379
Pituitary extract, 397
Nitrites, 406
Opium and Morphine (to allay restlessness), 261
(Calcium is useless, 569)

To remove fluid (dropsy, anasarca).

Digitalis series, 430
Diuretics (see Section IV).
Saline cathartics, 112
Sudorifics—Pilocarpine, hot and cold packs, 351
(Vegetable cathartics, 101)

IV. Drugs used for their effects on the genito-urinary system.

To increase the flow of urine (diuretics).

Caffeine and Theobromine, 296
Digitalis and Squills, 435
(Turpentine, Uva Ursi, Scoparius.)
(Pituitary extract, 397)
Saline diuretics and Urea, 300, 302
Iodides of the alkalies, 532
Carbonates, 550
Mercury—calomel and blue pill, 635

To lessen the flow of urine in diabetes insipidus.

Pituitary preparations, 397

To render the urine less acid.

Alkali carbonates and bicarbonates, 551
Acetates, 553
Citrates, 553

To make the urine more acid.

Acid sodium phosphate, 562
Acids, 561
(Ammonium benzoate, etc., 501)

To render the urine antiseptic.

(See pp. 132, 163).
Copaiba series, 165
Urotropine, 166
Salol and Salicylates, 166
Borax, 149
Local antiseptics, astringents, anodynes, caustics, etc., are used in the urethra and bladder.

To promote contraction of the uterus (ecbolics).

Ergot, 387
Quinine, 476
Pituitary extract, 397
(Pilocarpine, 352)
(Hydrastinine, 400)
Atropine is said to allay spasmodic contraction.

To promote menstruation (emmenagogues).

Iron, 646
Aloes, 101
(Myrrh).
Hydrastis, 400, is said to lessen menstrual flow.

V. Drugs used for their effects on the respiratory system.

To stimulate the respiratory centre.

Atropine, 341
Caffeine, 296
Strychnine, 285
Aspidosperma, 463
Carbonic dioxide, 5-10 per cent., 579
See also Oxygen, 580

To reduce the irritability of the centre in cough.

Opium, Morphine, and Codeine, 261
(Heroine, 261)
Chloral series, 243
Bromides of the alkalies, 270

To increase and liquefy the bronchial secretion. (See p. 445.)

Ipecacuanha, 448
Tartar emetic, 623
Squills, 435
Apomorphine, 445
Senega, 457
Ammonium carbonate, 551
Iodides of the alkalies, 532
(Lobelia, 319)

To lessen the secretion of the bronchi (?).

Benzoic acid, Benzoin, Tolu Balsam, 501
Ammonium chloride, 525
(Cubebs, 165)

To relax bronchia spasm in asthma.

Belladonna and Atropine, 340
Lobelia, 319
Nitrite series, 408
Iodides, 532
Adrenaline, 380
(Arsenic, 602)

Pulmonary disinfectants. (See p. 134.)

Creosote, 167
Guaiacol, 167
Tar, 160

VI. Drugs used for their effects on the central nervous system.

Stimulants

(*a*) *The spinal cord.*
Strychnine, 285
(*b*) *The brain and medulla oblongata.*
Caffeine, 296
Atropine, 341

Depressants.

(*a*) *To paralyze sensation—General anæsthetics.*
Ether, Chloroform, Ethyl chloride, Nitrous oxide, 228
(*b*) *To induce sleep and rest—hypnotics or narcotics.*
Opium and Morphine, 260
Alcohol, 195
Chloral group, 243
Bromides, 274
Hyoscine, 337
Cannabis indica, 269
(*c*) *In epilepsy.*
Bromides, 274
(*d*) *In hysteria.*
Asafœtida, 75

For surgical operations.

(*a*) General anæsthetics.
Chloroform, Ether, Ethyl-chloride, Nitrous oxide, 228
(*b*) Morphine and hyoscine, 262
(*c*) Cocaine and its substitutes by various methods, 368
(*d*) Local anæsthesia by cold, 74
(*e*) (Magnesium sulphate intraspinally, 574)

To relieve pain—analgesics or anodynes.

Opium, 259
Cannabis, 269
Antipyrine series, 490
(Alcohol, 195)
(Chloral, 243)

In headache.

Quinine, 475
Antipyretics, 490
Acetylsalicylic acid, 499
Caffeine, 296
Amyl nitrite, 408
Menthol externally, 73
(Arsenic, Iodides)

In cerebral congestion.

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Purgatives (croton oil), 101
Bleeding.
Cold to the head.

In cerebral anæmia.

Adrenaline, 379
Pituitary extract, 397
Digitalis group, 434

VII. Drugs used to reduce fever temperature.

Antipyrine and Acetanilide group, 488

Cold baths, 489
Quinine, 475
(Aconite, 440)
Salicylic acid group, 499

In chills. (See page 196.)

Ipecacuanha, 448
Opium, 262
Quinine, 475
Alcohol, 196

VIII. Drugs used for their effects on the liver.

To increase the secretion of bile—cholagogues.

Ox-gall, 119
(Salicylic acid, 499)

IX. Drugs used for their effects on the blood.

To increase the hæmoglobin.

Iron, 645
Arsenic, 602

To reduce leucocytosis.

Arsenic, 603
Benzene, 506
Quinine, 474

To increase the alkali.

Alkali carbonate group, 550
Acetates and Citrates, 553

X. Drugs used for specific diseases.

In malaria.

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Arsenic, 602

In syphilis.

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Arsenic, 603
Salvarsan, 611

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Antidiphtheritic serum, 503

In tetanus.

Antitetanic serum, 504
Chloral, 243
Bromides, 275
(Magnesium intraspinally, 574)

In cerebro-spinal meningitis.

Antimeningococcus serum, 505

In amœbic dysentery.

Ipecacuanha, 449
Emetine, 449

In rheumatic fever.

Salicylates, 497

In myxœdema and some other thyroid diseases.

Thyroid extract, 539
Iodides, 531

In trypanosomiasis.

Arsenic (atoxyl), 603, 607
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In gout.

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Atophan, 454

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Arsenic, 602
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(*Rickets and Osteomalacia.*)
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XI. Drugs used for their effects on the skin.

Corrosives or caustics, Section I.
Emollients and protectives, Section I.
Local anodynes and anæsthetics, Section I.

Irritants.

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